NATURE'S HYGIENE

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NATURE'S HYGIENE:

A Series of Essays

ON

POPULAR SCIENTIFIC SUBJECTS

WITH SPECIAL REFERENCE TO

THE CHEMISTRY AND HYGIENE OF THE EUCALYPTUS AND THE PINE.

BY

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PREFACE.

OF the many scientific subjects which, during recent years, have strongly arrested the attention of the public, few have excited more interest than that which has been manifested, from time to time, regarding the reputed sanitary properties of the eucalyptus tree. But while this interest extended even to several European and other Governments, and although the hygienic value of the eucalyptus is based upon an abundant and increasing amount of evidence, yet no satisfactory explanation of this influence has ever been presented to the public.

During some years I have spent much time in the study of what are known to chemists as processes of slow oxidation, and have communicated the results of my researches to various scientific societies. These investigations, conducted, so to say, in the laboratory of Nature, furnished a full and sufficient explanation of the sanitary properties of the eucalyptus tree, and they also proved that

the pine tree exhibits characters of the same important order.

In bringing this work, therefore, before the public, I am really endeavouring to place before them a scientific research in a popular manner. In so doing, however, I have not merely described my own experiments, but have also given particulars of those of all others who have worked upon the subject, and have incorporated the results in a number of chapters, which deal with a variety of questions more or less intimately concerned with Nature's Hygiene.

Each chapter will be found to form a complete essay in itself, and thus the book combines the features of a continuous study of some processes of Nature's chemistry and hygiene, and of a series of articles on scientific subjects.

Wherever an educated public is to be found, there must also exist a demand for popular scientific literature; and it is towards feeding such a demand that I have ventured to contribute this work, trusting it may not be received altogether without favour.

CHARLES T. KINGZETT.

12, Auriol Road,
West Kensington, W.
March 31*st*, 1880.

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NATURE'S HYGIENE.

CHAPTER I.

HISTORICAL NOTES ON OXYGEN, HYDROGEN, WATER, OZONE, PEROXIDE OF HYDROGEN AND ANTOZONE.

IN the early days of the Royal Society, when its meetings were held at Oxford, the Hon. Robert Boyle directed the attention of its members to a number of interesting experiments which he, together with his assistant Dr. Hooke, had made upon ordinary air. Among these observations he showed that animals which were confined in a limited volume of air died after a short time. John Mayow, who attended these meetings, being attracted by the interest of the subject, continued the research thus originated by Boyle and Hooke. He ascertained (1674) that in breathing, animals do not consume the whole of the air which is inspired, and that, indeed, the air consists of two gases, one of which is of no direct use in sustaining life. This gas we now know as "nitrogen."

It will be seen that Mayow had, as a matter of

fact, discovered "oxygen" gas, although in a negative sort of way; but owing to the erroneous views then prevalent, his discovery was allowed to be forgotten, or nearly so, for a hundred years. Then Priestley, who occupied himself with continued observations upon gases, succeeded—it may almost be said accidentally—not only in re-discovering oxygen, but also at the same time in making it from a solid substance. It will be remembered by all students of chemical history that, in 1774, Priestley obtained this gas by exposing the red oxide of mercury to a high temperature, and it further appears that Scheele (a Swedish apothecary of famous memory) made the same discovery both simultaneously and independently. Priestley not merely collected oxygen gas, but he ascertained also its powers to support combustion and maintain life. At that time he wrote, "Who can tell whether this pure air may not at last become a fashionable luxury? As yet, only two mice and myself have had the privilege of breathing it." * In spite of all this, he persisted in calling oxygen "dephlogisticated air," and very imperfectly understood his own results.

The Parisian Lavoisier (born 1743) was a man of his day. After revolutionising chemical science he himself was sacrificed to a political revolution. He introduced the balance into chemistry, and whereas Priestley had obtained oxygen and mercury from the red oxide, Lavoisier reconstructed the compound

* "Short History of Natural Science," p. 234. Buckley.

from its elements, and showed that when heated, a given quantity of the oxide gives off just the same amount of oxygen gas as is consumed in its preparation. In brief, he demonstrated that mercury and oxygen combine in definite proportions. Like all other discoveries made in science, Priestley's preparation of oxygen was not merely valuable in itself; it was also valuable as the cue to further investigation.

In 1766, Cavendish first obtained "hydrogen" gas by the action of sulphuric acid upon zinc, and on examining its properties, he found that if mixed with ordinary air, and exposed to a flame, it exploded, producing moisture. But it was not until after Priestley had made oxygen, he became fully aware of the fact that the explosion referred to was owing to the combination of hydrogen with oxygen. He repeated his experiments with pure oxygen, and thus formed water.

These various advances in chemical science gave rise to more correct theories than those formerly in common acceptance, and the new generation of chemists found in the improved system of chemistry a powerful aid to research. So powerful, indeed, was this aid, that the chronicler of science finds it a difficult and arduous task to collect and register the innumerable discoveries which have followed continuously since.

It was about ten years after the discovery of oxygen when Van Marum, of Holland, observed that when this gas was subjected to the passage of

electric sparks, it acquired a peculiar fishy odour; and it is said that shortly afterwards Cavallo discovered its disinfecting value, and applied it as a remedy to fœtid ulcers.*

In 1826, Dr. John Davy recognised the presence of a similar principle in the atmosphere, thus explaining the odour often referred to in history as having been observed during storms and periods of electrical disturbance. It was not, however, till 1839 that any precise knowledge was obtained regarding the substance in question. M. Schönbein, of Basle, who was then engaged in an investigation of the electrolytic decomposition of water, noticed the same odour in the apartment in which he conducted his experiments, and this led him to a prolonged research, having for its object the elucidation of the nature and properties of this gaseous principle, which from its odour he named "ozone."

He ascertained that a certain amount of this substance was contained in the oxygen evolved at the positive pole during the voltaic decomposition of water, and further observed a number of its oxidising effects.

The nature of ozone was a very difficult nut for chemists to crack, and one which has only been surmounted by men now living among us.

Schönbein at one time considered ozone to be a compound of oxygen with hydrogen; but to render this view clear to our readers it is now necessary

* "Ozone and Antozone," p. 4. By Dr. Cornelius B. Fox.

to refer to another discovery of paramount interest with that attaching to ozone.

In the year 1818 Thenard discovered peroxide of hydrogen, a substance which is remarkably similar to ozone so far as many of its properties and reactions are concerned. He obtained it by acting upon barium dioxide with dilute hydrochloric acid thus :—

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

Moreover, ozone and peroxide of hydrogen are formed together in the electrolytic decomposition of water. There is, however, one great distinction between these substances: ozone is a gas which is almost, or quite, insoluble in water, whilst peroxide of hydrogen is a liquid, and is essentially soluble in water. Not only this, but, of course, the composition of each is different, as may now be readily demonstrated, but was not then quite so clear.

Well, peroxide of hydrogen being oxygenated water,* or a substance containing in its molecule more oxygen than water does, and its oxydising characters being considered as due to the ease with which it parts with the extra oxygen, Schönbein was led to regard ozone as peroxygenated water, or in other words, a more highly oxygenated compound than peroxide of hydrogen. Thus, to use the notation now employed by chemists, Schönbein

* This must not be understood as aërated water, or water containing dissolved oxygen, but water chemically combined with more oxygen and not simply admixed.

represented ozone as H_2O_3, peroxide of hydrogen being H_2O_2 and water being H_2O.

Prof. Williamson supported Schönbein in this opinion, which was afterwards proved to be erroneous by a long series of investigations conducted by numerous chemists, among whom may be named Becquerel, Frémy, Marignac, De la Rive, Andrews, Soret, and Brodie. It was first shown that pure ozone is free from hydrogen, and therefore yields no water during combustion; next, it was demonstrated that the matter of ozone is identical with the matter of oxygen; and, finally, by the classical researches of Andrews and Brodie (the latter of whom particularly investigated the volumetric relations of ozone), that ozone is oxygen in a condensed state. Not condensed in the sense that a given volume of gas may be made to occupy a smaller space by the influence of compression, but in the sense that the constituent atoms are so arranged that each whole molecule of ozone contains three atoms in the space occupied by a molecule of oxygen consisting of two atoms. While this demonstration was due to Andrews and Brodie, the view which it proved to be correct is to be credited to Odling, who with a characteristic keenness of perception discerned the truth before it was established.

The superior oxidising powers of ozone, as compared with those of ordinary oxygen, are supposed to be due to the state of its density, to which reference has just been made.

The best proof that can be given of the identity

of the matter of oxygen with that of ozone, consists in the ease with which it is possible to convert oxygen into ozone, and to effect also the converse reaction. Suppose that we take 100 volumes of oxygen gas, and subject it to the electric discharge until it measures 92 volumes, we shall by this time have produced a definite amount of ozone. This can be shown by removing some of the gas and submitting it to different tests. But if, instead of taking any of the condensed gas away, we raise it to a temperature of, say, 288° C., we shall find that for the 100 volumes of oxygen originally employed we now once more obtain 100 volumes at the same temperature and pressure. In other words, ozone is resolved at an elevated temperature into ordinary oxygen.

This identity of oxygen and ozone is not the least more remarkable than the identity presented by carbon in its ordinary forms. We have carbon in the forms of the diamond, graphite, and lamp-black; and the properties of these substances are as diverse as those of ozone and oxygen. One fact must be stated in particular here, because when we get further on we shall find it of considerable importance. It is this: whereas when ozone is exposed to contact with many chemical substances it suffers decomposition, yielding up its third atom of oxygen to the oxidisable matter and liberating ordinary oxygen, yet when submitted to contact with ordinary turpentine the whole molecule of the ozone is absorbed; no oxygen remains behind. For a knowledge of this fact we are indebted to Soret.

Beyond the states of oxygen presented in the ordinary form of that substance and of ozone, Schönbein, in the course of his experiments, met with phenomena which led him to believe in the existence of yet a third form. Thus, in a letter addressed to Faraday,* he writes of "an ozone and an antozone, which, on being brought together, neutralise each other into common or inactive oxygen." In another place he seems to be self-contradictory, since he expresses his belief that ozone and antozone are simultaneously formed as part of the attendant phenomena of every slow oxidation. He was probably led to this erroneous view by the difficulty he found in explaining the oxidation of turpentine (a matter which we shall by-and-bye have to consider in detail).

It would scarcely repay us to study at any length the various experiments which led Schönbein to believe in the existence of "antozone." We may take, however, one of his experiences as representative of all. When peroxide of barium (BaO_2) is treated with sulphuric acid, peroxide of hydrogen is produced; thus:—

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

Now Schönbein considered that this process also produced antozone, for he states that he thus obtained a gas possessing many active properties of oxidation, but differing from ozone by the formation of peroxide

* *Phil. Mag.*, 1858, where a good account of Schönbein's speculations may be found.

of hydrogen when it is passed into water. Schönbein was not alone in this belief; but it was eventually proved beyond all doubt that no new substance is formed in the process in question, but merely oxygen containing peroxide of hydrogen in suspension. As is now well known, if the sulphuric acid be not too strong, peroxide of hydrogen is the main product; and, indeed, it is a modification* of this process which is now employed for the commercial production of that substance. If, however, the sulphuric acid be strong, or if the temperature be not carefully kept as low as possible, a quantity of oxygen gas is set free by the sudden decomposition of the peroxide of hydrogen, and bursting from the liquid mass into the gaseous form, it escapes, carrying in suspension vesicles of peroxide of hydrogen, and thus exhibiting the characters for which Schönbein claimed the existence of antozone. It must be remembered, in justification of this illustrious chemist, that in the experiment just considered, any oxygen that might be formed would be evidently in the nascent state, that is to say, just originated, and all chemical experience goes to show that substances in such a state are far more energetic in their actions than they are under ordinary circumstances. This may possibly arise in the instance under consideration from the atoms of oxygen being set free as atoms (not having time during the moment of their new existence to combine into the molecules constituting

* This modification consists in the substitution of hydrofluoric for sulphuric acid.

ordinary oxygen); but however this may be, we know now, thanks to the researches of Nasse and Engler and others whom we need not name here, that antozone has no existence as a chemical individual, and is merely peroxide of hydrogen diffused through a large volume of air.

The experiments described by Schönbein and his expressed personal views, induced most chemists at the time to believe that nearly all slow processes of oxidation are attended with the production of ozone and antozone (peroxide of hydrogen), and among such processes are those of the natural and slow oxidation of phosphorus, ether, and turpentine.

On the face of things, we should scarcely expect that the ærial oxidation of phosphorus would give rise to ozone now that we understand its atomic constitution, and since peroxide of hydrogen is the only agent of great resemblance to ozone, it is this substance we should rather expect to find where, as in the process of phosphorus oxidation, an active principle is met with. That peroxide of hydrogen is produced is now almost or quite certain. Thus M. Corne* in a paper entitled "A New Reaction or Iodates and Iodides," finds that the water in which phosphorus has been kept for some time, liberates iodine from a solution of these substances, and he concludes that this behaviour is due to phosphorous acid, while as a matter of fact it is a characteristic reaction of peroxide of hydrogen. This is important

* *Journ. de Pharm.* (4) xxii. 425.

if we remember that ozone, which gives the same reaction, is practically insoluble in water.

One thing, at least, is certain, viz., that the active agent produced as described, is either ozone or peroxide of hydrogen. It has been demonstrated by Marignac that the formation of the active agent requires the presence of water, and this in itself is a strong reason for doubting its ozonic nature. Assuming the active body to be peroxide of hydrogen, then, on the other hand, we see very clearly why the presence of moisture is essential, for peroxide of hydrogen is oxygenated water.

A. R. Leeds,* who regards the active agent formed by the oxidation of phosphorus as ozone, has described an apparatus by the use of which it may be freely obtained; and he finds that not only is it produced by the passage of air or oxygen over phosphorus partially submerged in water, but that it may also be obtained, and in greater quantity, by using a solution of potassic dichromate acidulated with sulphuric acid in the place of water. He found that the best solution to employ was one containing in every 1250cc.; 150cc. pure acid (H_2SO_4) and 25 grms. of the dichromate. By connecting the vessels containing the phosphorus and this mixture with appropriate tubes, Mr. Leeds ascertained that the amount of active agent generated in the first of a series of such vessels, was increased by causing the air containing it to pass through the second and third vessels, and so on. The temperature necessary for

* *Chem. News*, vol. xxxix., p. 157.

maximum production he fixed at about 24°C. Operating in this way he obtained an aerial product containing about 2·5 miligrams of estimated ozone to the litre, or about, that is to say, 0·2 per cent. by weight of ozone in air.

The estimations were made by first washing the air in water, and then passing it into a solution of potassic iodide, estimating the iodine thus liberated by means of a standard solution of sodic thiosulphite. Now, although at first blush it might be thought that the water would remove any peroxide of hydrogen which might be held in the gas, yet, as a matter of fact, this is not necessarily the case. Indeed, all the erroneous views which have been held about mythical antozone were due to the same misleading notion. As we have seen, antozone is only peroxide of hydrogen; but from the fact that it was obtained diffused through large volumes of air, it was put down to be a distinct substance. It is therefore probable that the washing with water, to which Mr. Leeds subjected his gaseous product,* did not remove the peroxide of hydrogen therefrom, and so he estimated it as ozone, and considered it to be such.

All practical chemists are aware of the difficulty experienced in separating two gases by means of a solution in which one or the other is soluble. For instance, it is a common experience to pass a mix-

* In connection with this subject it is important to bear in mind that in his experiments (described in the "Philosophical Transactions" for 1856, p. 1), Andrews, while he writes of ozone as produced by

ture of carbonic oxide and carbonic anhydride gases (obtained as joint products in certain chemical reactions) through a solution of caustic potash, in order to remove the carbonic anhydride; and also as a matter of experience it is found that, except under special circumstances, it cannot be entirely removed in this way. To be successful, it is essential to use a large surface of the alkaline solution, and to make the gases pass through and over the entire length of this surface. This can be readily understood if we consider that a gas consists of particles of matter comparatively widely removed from each other; consequently, when a bubble of gas is made to pass into and out of a fluid quickly, there is no sufficient opportunity for every particle of the gas to come into contact with the fluid substance. Thus, in the instance above given, a few particles of the carbonic anhydride may escape such contact, unless, by the use of a proper arrangement the gas is made to pass over a large surface, when by its own molecular motion, supplemented by a physical impetus, this is specially prevented. At any rate, the active product formed in the oxidation of phosphorus has never been shown to possess the volumetric and special properties of ozone; and until this is done, and while

the oxidation of phosphorus, yet adduces no proof of this statement. He merely shows that by shaking such active air with water, the ozonic properties are removed from the gas. Supposing the agent to be peroxide of hydrogen, diffused through a large bulk of air in an ultra-vesicular state, and not ozone, this result would be readily explained by its known solubility in water.

See also a critical essay by the Author, *Chem. News*, vol. xl., p. 96.

its only observed properties are those common to peroxide of hydrogen and ozone, we must rather consider it to be the former substance. This conclusion is justified by many considerations, while more than one chemist * claims to have established its correctness beyond all doubt.

As regards the slow oxidation of the ethers, this is a matter which has received some study from the writer; and although the research is far from complete, it seems to show that ozone is never formed as a product of such reactions. On the other hand, the process never failed to yield peroxide of hydrogen, exhibiting all its well-known reactions and qualities. †

The atmospheric oxidation of turpentine and other similar substances has been a special study with the author for many years, but this is a subject which, from its nature and extent, demands exhaustive treatment in a subsequent chapter.

Note (*added since writing the foregoing chapter*).—My paper, published in the *Chemical News* (vol. xl., p. 96), led Prof. McLeod to make some experiments with the active agent produced during the slow oxidation of phosphorus, and he has lately communicated these to the Chemical Society (see *Journ. Chem. Soc.*, Feb. 1880, and *Chemical News*, vol. xl., p. 307). Relying upon the fact that peroxide of hydrogen is readily destroyed by alkalies, chromic acid, and alkaline permanganate of potash, while ozone is supposed to be unaffected by these substances, he has concluded that it is ozone, and not peroxide of hydrogen, which is produced in the reaction under study. It is true that, according to McLeod's experiments,

* For instance, D. J. Boche (*Deut. Chem. Ges. Ber.*, vi. 439).

† *Chem. News*, vol. xxxiv., p. 135.

the active body is not (at least not entirely) destroyed by the substances above named; but this result may be owing to its intensely diluted state, mixed as it is with an enormous bulk of air. Then he made some further experiments in which the active air was first heated to various temperatures and then passed through a sulphuric acid tube, and finally through a mixture of potassic iodide and starch. The iodine set free was determined by titration with sodic thiosulphate. The following results were obtained:—

Gas aspirated.	Temperature of U tube.	Increase of sulphuric acid tube.	Thiosulphate used.
4600 cc.	Cold	0·0026 grm.	2·55 cc.
2760 cc.	100°C.	0·0008 ,,	1·9 cc.
4600 cc.	150°C.	0·0026 ,,	3·2 cc.
2760 cc.	200°C.	0·0006 ,,	1·8 cc.

Prof. McLeod assumes that 200°C. would decompose at least one-half of any peroxide of hydrogen which might be present in the aspirated gas, and if so, then the weight of the sulphuric acid tube in the last experiment should be increased, not by 0·0006 merely, but by ·0016 grm. But this assumption was not based upon experimental evidence, and in my opinion is probably erroneous, considering the attenuated state of the active agent. Even if we make the assumption, the figures are within the limits of error. That the heat effected little or no decomposition seems certain, since if we recalculate the results for 1000cc. gas aspirated, we get the following figures:—

		Thiosulphate.
Exp. 1	1000cc gas required	0·55 cc.
2	,, ,, ,,	0·67 cc.
3	,, ,, ,,	0·69 cc.
4	,, ,, ,,	0·65 cc.

But no conclusion can be safely drawn from these figures, because the active air experimented upon was not of an uniform composition. Whether, then, it was ozone which thus escaped the action of the heat, or vesicular peroxide of hydrogen in an extremely diluted state, is not decided satisfactorily by Prof. McLeod, and we must yet wait

for more exact and searching inquiry to settle the very opposite statements which have been placed on record. In reply to my question, Prof. McLeod said he had often examined the water in which phosphorus had been oxidised, but had not found it to give a reaction with potassic iodide and starch. This statement is directly opposed to M. Corne's result referred to above, and to my own experience.—AUTHOR.

CHAPTER II.

OXYGEN, OZONE, AND PEROXIDE OF HYDROGEN: THEIR OCCURRENCE IN NATURE, AND GENERAL CHARACTERS.

Oxygen.

THE elementary substance, oxygen, may be prepared in the laboratory by a number of methods, the simplest of which consists in exposing certain metallic oxides to high temperatures, when oxygen is set free in the gaseous form, leaving the metals or lower oxides behind. Thus, as already stated in Chapter I., Priestley first obtained the gas by heating oxide of mercury. Oxygen is best known, however, as a constituent of the air we breathe, serving in the process of respiration to oxidise or burn up the carbonaceous matters presented to it in the blood of animals, and with which it comes in contact through the medium of the lungs; in this way carbonic anhydride is formed, and escapes as part of the breath into the atmosphere. From very careful investigations conducted by eminent observers, it has been calculated that in this way 8·5 ozs. of carbon are respired as carbonic anhydride in every twenty-four hours. Not only is oxygen thus consumed in the body, but 15 per cent.

of that absorbed during respiration is supposed to be used up in the fixing of hydrogen as water. Altogether, then, we find that 26·7 ozs., or more than 1½ lbs. of oxygen, are consumed daily by every adult. This weight of oxygen measures at the ordinary temperature and pressure no less than 529,400 cubic centimetres, or about 117 gallons.

These figures give some idea of the process known as respiration, and lead to the perception that respiration is not wholly expressed by saying it maintains life. It is seen to mean something more than this; for if we take the quantity of oxygen absorbed daily by each individual and multiply it by the number of the world's inhabitants, we shall obtain an astounding figure representing the sum total of oxygen daily removed from the atmosphere by human beings. Of course this quantity is increased by the amount also consumed by other animals, and it at once becomes evident that there must exist some natural process of restoration to the atmosphere of the oxygen thus removed, or otherwise in the course of ages the atmospheric proportion of this gas would grow so small that life would become impossible.

On inquiry, it is found that plant life furnishes back to the atmosphere the oxygen which animal life takes away from it. It is a fact that the growth and development of vegetation depends upon its elimination of oxygen from the very carbonic anhydride which animal life pours into the atmosphere. Priestley, who discovered oxygen, observed, for

instance, that a pot of mint kept under a bell jar containing air which had been rendered impure by breathing, influenced the air in such a way as to make it fit to breathe over again. In short, the mint decomposed the carbonic acid, assimilating the carbon and restoring the oxygen to the air. What mint did in this simple experiment is also performed by the green parts of all plants and vegetables, and particularly by the leaves.

In this way the composition of the atmosphere, which is a mixture of 21 parts of oxygen with 79 parts of nitrogen, is kept practically constant and universal. It may be remarked here that other substances are found in the atmosphere; but so far as these concern the subject of this treatise, they will be elsewhere considered.

Of course it will be understood that, although the composition of the atmosphere is of a fairly constant nature, yet its actual percentage composition is not entirely uniform. For instance, in the midst of a dense assembly of men gathered together in a room, there would be found proportionately more carbonic acid and less oxygen in the air than in fresh country air; but there exists a law of nature which militates against such circumstances, and eventually overpowers all such localised effects. If we mix castor oil and water together, they will eventually separate, in spite of any amount of shaking, into two layers; but a similar behaviour is not observed with gases of different densities. Thus if a heavy gas be brought into contact with a much lighter gas, the

two will uniformly diffuse one into the other, and will not afterwards separate. This can be readily appreciated if it be borne in mind that gases consist of particles of matter widely separated from each other; hence the particles of one gas can move into the spaces between those of another. This power or force of gaseous diffusion serves to prevent any evils which might arise from differences in the composition of the atmosphere owing to local circumstances.

In the vicinity of limekilns, and in the neighbourhoods of human habitations, etc., much carbonic acid is, of course, generated into the surrounding air; but, instead of remaining in the locality, it is carried away by the power of diffusion, and uniformly distributed in atmospheric space. Aërial currents materially assist, of course, in carrying out this process.

At ordinary temperatures and pressure, oxygen is a colourless gas; but it has been recently demonstrated by M. Raoul Pictet and M. Cailletet that when subjected to the joint influences of a very low temperature and extremely great pressure, it assumes the liquid form.

If we consider that oxygen is truly what the older chemists termed it,—viz., vital air,—it is not surprising that a small animal should be able to live longer in a confined space filled with the gas than in an equal volume of air containing, as it does, a large proportion of nitrogen. Nevertheless, oxygen cannot be breathed with impunity for any length of

time; and, indeed, when inhaled in the pure state, it exercises a severe poisonous effect. M. Paul Bert, who has devoted much time to the study of this subject, found that oxygen acts as a rapid poison when arterial blood contains 35 per cent., or nearly double the normal amount; the convulsions and death which result being due to a great exaggeration of the excito-motor power of the spinal cord. Compressed air exerts a similar influence. In dogs, convulsions begin when the external pressure of oxygen is about $3\frac{1}{2}$ atmospheres, or 17 atmospheres of air, and death occurs at 5 atmospheres of oxygen.

From these facts we see the reason why, as found in nature, the oxygen of the atmosphere is diluted to so large an extent with nitrogen which is innocuous to health. By this dilution the oxygen is rendered powerless to produce the evil results which follow when the pure gas is breathed, while its power to oxidise the matters presented to it in the blood is not in any way impaired.

As Liebig is reported to have said that the best reagent for ammonia is the nose, so it may be said oxygen is characterised by its power of oxidation. In cases where this process is carried on rapidly, so that it is attended with the evolution of light and heat, combustion is said to occur. For instance, if a piece of charcoal be ignited and then thrown into a globe filled with oxygen, the oxidation, which in the atmosphere merely kept the charcoal at a dull red heat, is now so intensified that its combustion is continued with great avidity.

In an ordinary grate fire we have the best illustration of the process of oxidation; the coal and wood, being of a carbonaceous nature, only require the application of heat to enable the oxygen in the atmosphere to enter into chemical combination with their constituent particles, and when once this process of combination has commenced, the heat with which it is attended is sufficient to keep the combustion (oxidation) going. In this way the carbon of the fuel combines with the atmospheric oxygen to form carbonic acid. As a matter of fact, then, respiration is a kind of combustion, since the same kind of thing goes on in the two processes, and is attended with identical results; the only difference between combustion and respiration being one of outside conditions.

If the atmosphere consisted entirely of nitrogen, it would be just as impossible for a fire to occur as it would be for animals to exist; combustible matters and the oxidisable principles of blood equally requiring oxygen wherewith to combine. This process of oxidation or combustion is one which will have to be considered more fully hereafter, and the few words said about it here will pave the way for more important considerations.

Beyond its power to maintain life and support combustion, oxygen gas exhibits but few direct chemical reactions which are not also shared by ozone and peroxide of hydrogen. It differs from these two last named substances, however, in being less active in its properties. Thus, when brought in contact with

a solution of iodide of potassium, it exercises no influence upon it. It has no colour, taste, or smell; it is only slightly soluble in water, 100 volumes of this fluid dissolving 4·11 volumes of the gas at 0°C., and 2·99 volumes at 15°C. (ordinary temperature).

It has no action on litmus paper and does not oxidise silver, while it is stable at all temperatures. In oxygen, therefore, we have a substance of such marked general negative characters, that we can readily and unmistakably discriminate between it on the one hand and ozone and peroxide of hydrogen on the other hand.

Ozone.

The presence of ozone in the atmosphere was first assumed when Dr. John Davy obtained certain reactions with ordinary air, considered then to be characteristic of ozone; and as Cavallo and others had found ozone to possess marked disinfecting powers, more importance was attached to atmospheric ozone than the subject perhaps deserved.

The observations of Dr. Davy were repeated and extended; and as the oxidising powers of ozone became better known, there arose in the minds of men the idea that this substance constitutes nature's purifier. This idea received the more credence since Schönbein had taught that every process of slow oxidation occurring in nature is accompanied by the formation of ozone, and from the researches of Kossman and Daubeny, who stated that under certain conditions the same substance was produced by the green parts of plants.

The amount of work which has been devoted to the study of ozone as occurring in the atmosphere, and its relation to storms and winds, is almost beyond belief, and the task of collecting or summarising such investigations would be perhaps one of supererogation. It will certainly not be attempted here, and more particularly since Dr. Fox has very carefully performed the task already.* To his work we refer the reader who may feel disposed to proceed upon the study, while for the purposes of this treatise it will suffice to bring two facts prominently before the reader's mind. In the first place, then, the majority of persons undoubtedly attach great importance to atmospheric ozone and believe it to be the greatest purifying influence in nature; many going so far as to assert that zymotic disease exhibits a definite relation to ozone in the sense that when ozone is absent from the atmosphere, disease occurs and spreads, and that where present, zymotic disease is almost unknown. It seems a vast pity to upset notions which have taken so deep a root in men's minds, but the truth must be told by scientific men, and the truth is, that nearly all the observations which have been made on the subject are inconclusive.

It was pleasant enough to resort annually to the sea-side in the firm belief that there ozone occurred plentifully, and miasmatic poisons could not endure; but, as a matter of fact, there is little evidence to show that, so far at least as ozone is concerned, the

* "Ozone," etc. By Dr. Cornelius Fox. Churchill.

seaside is any healthier than the flats and marshes of Lincolnshire or the hills of Devonshire.

And now one word in explanation. The chemical reagents and tests which have been applied by different observers in determining the presence and amount of ozone in the atmosphere under various circumstances are not alone influenced by ozone; they are also influenced by peroxide of hydrogen, and there is at present no reliable and practicable method for testing and estimating the one substance without the other.

There is generally some amount of truth in any doctrine or belief which may be held by a large number of persons, and as the reader of the foregoing sentences may have suffered some discomfort in feeling that his pet theory was here demolished before his ace, it is pleasant to restore the comfort, and place it upon a more enduring basis. The reader, then, may rest content in the assurance that even if ozone does not occur in the air so freely as he previously believed, yet another substance does, and one, too, of equal sanitary value, viz., peroxide of hydrogen. Although it cannot be said with certainty that ozone ever occurs in the atmosphere at all, its presence in minute amount is very probable, and more particularly because there are times and conditions when ozone must, presumably, be produced in the atmosphere. It must yet be distinctly understood that there is no known test for ozone admitting of application which is not also affected by peroxide of hydrogen. For example, when Dr. Daubeny in

1866* stated that his researches tended to show that atmospheric ozone is generated almost exclusively by the green parts of plants, he was guided by the fact that with the oxygen emitted by plants in the daytime there is also given off an active agent which liberates iodine from iodide of potassium: this result, however, is producible by peroxide of hydrogen, and up to the present moment we do not know with certainty whether it is this agent or ozone which is thus produced, if either.

Dr. Daubeny was supported in his views by M. Kossman and many others; but M. Cloez, from some carefully conducted experiments, arrived at the conclusion that the liberation of iodine and consequent colouration of the ozone test-papers in Daubeny's experiments was due to the combined action of humid oxygen and solar light upon the iodide of potassium.

Prof. J. Bellucci† passed currents of air free from ozone through bell-jars containing living plants or recently cut branches and leaves, and he found that if the tubes containing the air were protected from daylight, when it came in contact with the potassium iodide test and after contact with the plants, then no ozone reaction was obtained, thus supporting the statement of Cloez.

In experiments of the kind just described, care must be taken not to employ plants of an aromatic nature, since, as will be afterwards explained, peroxide of hydrogen is certainly produced by them.

* See *British Association Report*, also *Journ. Chem. Soc.*, 1867, 19.

† *Compt. Rend.*, lxxviii., 362.

As plant life, therefore, does not seem to generate atmospheric ozone, its source must be looked for elsewhere.

Now, as in the laboratory ozone is most easily prepared by the action of electrical discharges upon oxygen or air, and as electrical discharges are constantly occurring in the atmosphere, it is most probable that we shall find here the explanation we are looking for. Moreover, there are numerous sources of atmospheric electricity. Of course, in storms attended with lightning, there is the strongest reason for believing that ozone must necessarily be produced, and peroxide of hydrogen also.

A. Houzeau found * that country air contained a maximum of 1·450000 of its weight, or 1·700000 of its bulk of ozone, and considered it to be produced by atmospheric electricity constantly acting in the manner of a huge-sized condenser between the soil and the clouds.

It is also probable that the friction of water-drops as they fall in the form of rain against the air, produces negative electricity; as it is also certain that the spray of a fountain, waterfall, or cascade, likewise charges the surrounding air with negative electricity, which, acting upon the oxygen of the air, gives rise, in all probability, to the formation of ozone. That this is so, is supported by various experiences which have been summarised by Prof. Bellucci in a most interesting paper.† In this communication he points out :—

* *Compt. Rend.*, March 11th, 1872.

† *Gaz. Chimica. Italiana*, vi., 88-97.

1. Lender noticed an ozone reaction in the air near the columns where the concentration of brine is carried out at Kissingen; the air here is filled with the spray of the salt-water.

2. Gorup-Besanez found that a similar reaction could be observed with the spray of water containing no salt, and that the ozone formed by a spray of water issuing under pressure was greater the more rapid the evaporation.

3. Morin and Monte also found that ozone is produced during the pulverisation of water.

4. The author (Bellucci) observed at Terni, near the falls, a similar ozone reaction, and concludes that it is traceable to the electrical state induced by friction of the minute waterdrops.

Now if it be true that the friction of waterdrops against the air is sufficient to give rise to ozone, then how great must be the quantity produced over the surface of the oceans! Thus, after all, it may be that sea-air abounds in ozone. At the same time it must be remembered that the fact has not been demonstrated by unequivocal tests.

It may, in conclusion of this part of the subject, be assumed, then, that ozone is a tolerably constant ingredient of pure air, although never present except in traces. The amount of it present in different places is extremely variable, as its production is dependent upon conditions not always in force, and, further, since it is readily destroyed by oxidisable matters generally, and particularly by organic matter in a state of change or decomposition.

In the laboratory, ozone is prepared by the action of electricity upon air or oxygen. Andrews and Tait showed that, to produce the maximum amount of ozone, it is best to transmit the electrical discharge silently, as the passage of the spark itself destroys a quantity of the ozone previously formed. Or, as Siemens first showed, ozone may be obtained by submitting a current of oxygen to the action of induced electricity. It forms no part of the present work to describe the different arrangements of apparatus for preparing ozone. Many of these have been described by Dr. Fox in his work on ozone, while all of them are constructed upon the principles given above. We pass on, therefore, to consider the properties of ozone.

In its natural state, ozone is a gas of greater density than oxygen, so that a given amount of it occupies a less volume than that of the oxygen from which it is made. Indeed, the preparation of ozone from oxygen may for purpose of illustration be thus written :—$3O_2 = 2O_3$. That is to say, three volumes of ordinary oxygen become, under the influence of electrical action, transformed in two volumes of ozone. At temperatures a little above the boiling point of water, ozone is slowly retransformed into oxygen, and this change is instantaneous at 300°C. With the change back into oxygen, there is an increase of volume exactly corresponding to the diminution observed when oxygen is converted into ozone; and of course all the ozonic properties are simultaneously lost, being substituted by those of ordinary oxygen.

There still seems to be some doubt as to the solubility of ozone in water. Most books state that ozone is quite insoluble in water, while Soret stated that water absorbs a certain amount of ozone. This statement of Soret has been confirmed by L. Carius,* who passed ozone (obtained from the electrolysis of a large surface of dilute sulphuric acid at 0°C) through water maintained at 2° to 4°C, and found that in this way the water absorbed about 4 or 5cc. of ozone. He also found the "ozonised water" of Krebbs, Kroll, & Co., to contain a similar quantity of ozone, and to be quite free from peroxide of hydrogen.

On the other hand, C. Rammelsberg † found Krebbs & Co.'s water to contain 0·16 per cent. chlorine (which would give the same reaction with potassic iodide, as that by which Carius estimated his ozone), and that such a product could be obtained by passing air first through a solution of bleaching powder (chloride of lime), and then into water. In all his experiments made with a view of obtaining true ozonised water, he failed.

Em. Schöne,‡ however, experimenting with ozone got by the silent discharge method, found that ozone is soluble in water to the extent of about 8·81cc. ozone per litre, and that no peroxide of hydrogen is formed by action of the ozone upon the water.

Air highly charged with ozone exerts an irritating effect upon the respiratory organs; and when an

* *Phil. Mag.* (4) xliv. 544.

† *Deut. Chem. Ges. Ber.*, vi. 603-605.

‡ *Deut. Chem. Ges. Ber.*, vi. 1208 and 1224-1230.

excess of ozone is breathed, certain symptoms reminding of catarrhal and bronchial affections are induced. This is not surprising, for even pure oxygen cannot be breathed with impunity, and naturally ozone must exercise in the system a much more powerful action than ordinary oxygen.

Of course it will be readily understood that these facts express the pathological rather than the physiological properties of ozone, and they are only true of an excess of ozone,—such an excess, indeed, as probably never occurs in nature.

The idea that ozone is naturally generated in the blood through an action exerted by the red corpuscles upon oxygen is one which does not rest upon a satisfactory basis.

Ozone possesses powerful bleaching powers, and converts blue indigo into colourless isatin; curiously enough, however, it seems to have little action upon the colour of flowers, a fact pointed out by A. R. Leeds,* and noted by him as an economical feature in "nature's purifier and disinfectant." The oxidising effects of ozone are very powerful, and are exhibited even towards such metals as silver and mercury: silver becomes peroxidised under its influence, whereas this metal is not at all affected by oxygen. Ozone also oxidises iodide of potassium, setting free the iodine from its solution; and it is upon this reaction that the estimation of ozone is most readily effected.

There are easy chemical methods by which free

* *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

iodine can be estimated; hence, when ozone is present in sufficient amount, nothing is easier than its determination by estimating the iodine set free by it. If the quantity be too small, it can be judged of by the depth of colour it imparts to a paper previously steeped in a mixture of iodide of potassium and starch. Unfortunately, however, other chemical principles act upon potassic iodide in the same way, and thus experiments of this kind, except under special circumstances,—as, for instance, when the substance is known to be pure ozone,—are of little conclusive value.

Its oxidising effects are also readily demonstrated by the ease with which ozone deodorises putrid meat and effusions. Thus in 1854 Drs. Wood and Richardson* exposed a pint of coagulated ox blood to the air for a whole twelvemonth, by which time the mass had become a most offensive fluid. In 1862, and when it was still most horribly offensive, it was subjected to a current of ozone generated by Siemens' apparatus. By this means the evil odour was gradually and entirely removed, and the resulting product was perfectly sweet to smell.

Schönbein also observed† that "air containing only 1·3240000 of ozone has the power of disinfecting its own volume of air loaded with the effluvia emitted in one minute from four ounces of flesh in a highly putrid state."

A. Boillot‡ has further noticed that fresh beef

* See Fox's work on Ozone, p. 30. † *Ibid.*, p. 94.

‡ *Compt. Rend.* lxxxi., 1258.

was preserved in ozonised air for more than ten days, while in ordinary air a part of the same beef went bad in five days.

Peroxide of Hydrogen.

This substance is a very remarkable one, and differs essentially from oxygen and ozone in being a liquid at the ordinary atmospheric temperature and pressure. It may be produced in the laboratory by several processes, some of which have been already mentioned in preceding paragraphs. Thus, in the electrolysis of acidulated and saline solutions, when ozone is formed, a small quantity of peroxide of hydrogen is also produced, so that even at very low temperatures, water, when subjected to electrolysis, does not yield quite the theoretical amount of oxygen, it is always slightly below the true figure; and it is this deficiency of oxygen which goes to form peroxide of hydrogen by combination with water.

F. Le Blanc * believes that the peroxide of hydrogen produced during the electrolysis of acidulated water, is due to the action of ozone upon the water. This, however, is improbable for more than one reason, and while there is no evidence in favour of the idea, Schöne has expressly satisfied himself to the contrary by careful experiments.

It may be prepared by suspending baric dioxide in water, and passing a current of carbonic acid gas

* *Compt. Rend.* lxxv., 537.

through the mixture. The following equation represents the changes which occur :—

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2.$$

That is to say, the carbonic anhydride unites with baryta to form the insoluble carbonate, whilst the second atom of oxygen in the dioxide of barium unites with the water as liberated, to form the hydric peroxide.

As made in this way, the peroxide is very dilute, so that for all practical purposes it is better obtained by treating the peroxide of barium suspended in water, with the theoretical amount of dilute sulphuric acid required to fully react upon it, as follows :—

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2,$$

or, as better shown :—

$$BaOO + H_2OSO_3 = BaOSO_3 + H_2OO.$$

The sulphate of barium forms a white insoluble precipitate, while the peroxide of hydrogen passes into solution at once.

For commercial uses, it is prepared by a similar process to that just described, only in the place of sulphuric acid, hydrofluoric acid or hydro-fluosilicic acid is used, and either insoluble fluoride or fluosilicate of barium is formed, peroxide of hydrogen alone remaining in solution.

The occurrence of peroxide of hydrogen in nature, until quite recently, attracted but little attention, and this is not surprising if it be considered that

there were but slight means of distinguishing between it and ozone. Moreover, many of the natural processes now well known to generate peroxide of hydrogen were up to the last few years regarded exclusively as sources of ozone. In fact, the peroxide of hydrogen, giving the same tests, was mistaken for ozone.

Not only Schönbein and Dumas thought it probable that peroxide of hydrogen should occur in the atmosphere under certain circumstances more guessed at than determined, but Prof. Struve * claimed, in 1869, to have demonstrated its presence in the air as a product of simultaneous formation with ozone, and states that the colouring of iodized starch paper when exposed to the atmosphere, is the joint result of the influences of ozone and peroxide of hydrogen. He also pointed out that peroxide of hydrogen may be condensed in rain-water.

Since that time, much attention has been given to this subject by various observers, and particularly so since the author of this treatise discovered that all kinds of aromatic plants produce peroxide of hydrogen liberally. The way in which they do this is reserved for special treatment in a separate chapter, and here the mere statement may be submitted, that probably every plant and flower of perfume (including all those which are known to secrete essential oils), generates peroxide of hydrogen into the atmosphere, by the joint or successive action of air and water upon the said oils and perfumes.

* *Comptes Rendus*, 1869.

Em. Schöne * found more peroxide of hydrogen in a litre of dew or hoar-frost during the summer months than during the winter months. In a lecture-hall which had been closed for some weeks, he also found about 0·17cc. peroxide of hydrogen (H_2O_2) in 1000 cubic metres of air.

It will be understood that, as peroxide of hydrogen is abundantly soluble in water, its presence in rain-water or dew is not at all surprising. As the rain or water-drops fall through or condense from the air containing the peroxide of hydrogen, this latter substance of course dissolves in the water.

In a subsequent communication † Schöne found that "the higher above the earth's surface the condensation of atmospheric aqueous vapour takes place, the richer in peroxide of hydrogen is the resulting precipitate." This also is quite intelligible, since peroxide of hydrogen, like ozone, is unstable, and is readily decomposed by organic matters generally,—which matters are most abundant near the earth's surface.

Then again, Schöne finds ‡ that in the strata of the atmosphere accessible to investigation, the peroxide of hydrogen is greater the higher the sun rises above the horizon, both during the day and the year, and the smaller the obstructions to the sun's rays. He considers, therefore, that the amount of peroxide of hydrogen should notably increase

* *Ber. Deut. Chem. Ges.*, No. 6, 1878.
† *Ibid.*, No. 8, 1878.
‡ *Ibid.*, No. 9, 1878.

towards the equator. This consideration is very probably a correct one, for in the tropical regions, vegetation abounds most freely; and here it is that we meet with one of the great sources of peroxide of hydrogen. In these huge areas of vegetable life, every oil-secreting tree or plant is giving rise to the production of peroxide of hydrogen as before mentioned.

M. Sergius Kern, following up the experiments of Schöne, has more fully examined rain-waters,* and he finds that equatorial winds bring rains much richer in peroxide of hydrogen than the rains carried by polar winds, thus lending some sort of confirmation to the above-expressed views.

Further, it has been pointed out by A. R. Leeds † that papers which have been moistened with potassic iodide and starch (Osann's test papers) are not generally coloured at Hoboken, but only tinted on rare occasions. On the other hand, in Keene Flats, N.Y., the days were few on which no indication was obtained. It should be stated that the place of investigation in Keene Flats was 700 feet above the sea level, and the surrounding vegetation was chiefly deciduous. At a point near the upper end of Upper Saranac Lake, which is even at a much greater altitude and surrounded with miles of primitive forestry embracing hemlocks, pines, larches, and spruces, the woods being often redolent with balsamic odours and extensively used as a health

* *Chem. News.*, vol. xxxvii. p. 34.

† *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

resort by large numbers of patients, Mr. Leeds found the most intense and frequent reaction with the test-paper named. Although in his published papers he assumes this active constituent of the air to be ozone, the test employed, as already explained, is one equally sensitive to peroxide of hydrogen, whose very home is forestry embracing pines and spruces. It is certain, indeed, that the colouration of the test-papers was due to peroxide of hydrogen.*

M. J. Clermont † avers that he has detected the presence of peroxide of hydrogen in the juices of many bruised plants, such as the tobacco plant, the vine, lettuce, etc. The test, however, which he employed is just as characteristic of nitrites (which are far more likely to be present) as it is of peroxide of hydrogen. His statement having received no kind of confirmation, and a direct refutation at the hands of Prof. G. Belucci,‡ it may be dismissed as erroneous.

S. Cohné § has described some few simple experiments which, according to his interpretation, go to show that certain parts of plants, by contact with peroxide of hydrogen, give rise to ozone. In the same journal ‖ the writer has critically examined Cohné's experiments, and has shown that his results admit of another and more plausible explanation. Peroxide of hydrogen, even in dilute solutions, undergoes

* *Chem. News*, vol. xxxviii., p, 243 (critical note by the author).

† *Comptes Rendus*, No. 25, June 28th, 1875.

‡ *Gaz. Chim. Ital.*, Anno viii., 1878. Fasc. vii. and viii.

§ *Chem. News.*, vol. xxxiv., p. 4.

‖ *Ibid.*, p. 20.

slow spontaneous decomposition into water and free oxygen, and this decomposition is accelerated by contact with many substances. For instance, meat fibrin exhibits this contact-power in a remarkable degree; and it is not improbable that the fibrin of plants possesses a similar power, more particularly since, as Cohné himself shows, a stem is most active where it has been cut through. Now, in such a decomposition of peroxide of hydrogen, the oxygen escapes from a solution known to react with the test-mixture employed, and as the bubbles of gas escape from the fluid, they are probably saturated with the peroxide of hydrogen, just as ordinary air contains moisture. It is this escaping hydric peroxide (which might also be carried up as spray) that Cohné evidently mistook for ozone. Thus, there is as yet no kind of proof, either that ozone in the presence of water yields peroxide of hydrogen, or that peroxide of hydrogen can give rise to ozone.

Nevertheless, A. Houzeau * thinks that in certain cases—for instance, when ozone acts upon sulphindigotic acid—peroxide of hydrogen is intermediately formed in solution. This is by no means improbable; indeed, it is certain that other processes of oxidation also give rise to peroxide of hydrogen, both intermediately and finally. Thus, P. Schützenberger, in the course of some interesting and important experiments,† met with results which

* *Comptes Rendus*, lxxv., 349-351.

† *Bulletin de la Société Chim. de Paris*, vol. xx., p. 145. 1873.

led him to the conclusion that peroxide of hydrogen is produced by the action of air or oxygen upon hyposulphite of sodium. It is also formed as a product of the atmospheric oxidation of that class of hydrocarbons known as terpenes, and of which turpentine is illustrative.

Having now briefly considered the various processes by which peroxide of hydrogen is formed, we will shortly describe its nature and more important reactions. It has been explained (in an earlier chapter) that water was found by Cavendish to consist of hydrogen in combination with oxygen. In other words, two volumes, or atoms, of hydrogen when exploded with one atom or volume of oxygen, combine and form one molecule (two volumes) of water :—

$$H_2 + O = H_2O.$$

Now peroxide of hydrogen contains one more atom or volume of oxygen than does water in its molecule, and so it is represented by the formula H_2O_2.

By careful concentration of dilute aqueous solutions *in vacuo* at low temperatures, it may be obtained in the form of a syrup which is colourless and has a faint odour, reminding both of chlorine and ozone. The fluid is, however, very unstable, and slowly undergoes decomposition, even at ordinary temperatures, as follows :—

$$H_2O_2 = H_2O + O,$$

the oxygen gas escaping in the form of minute bubbles. This decomposition is assisted by the contact of many substances (notably alkalies), and par-

ticularly by those which are themselves in a state of change or decomposition. On the other hand, the presence of a little ordinary ether restrains the decomposition; and not unlikely the reason for this is to be found in the fact elsewhere noticed, that ether itself gives rise to the production of peroxide of hydrogen by contact with air or oxygen.

If the syrupy solution of peroxide of hydrogen be heated to the boiling-point of water, it suddenly decomposes, and the oxygen escapes with explosive violence.

The liquid is miscible with water in all proportions, and it is generally stated in books that, although dilute solutions are more stable than strong ones, yet even dilute solutions are immediately decomposed on ebullition. Indeed, this method has been advocated as a good means of estimating the strength of the peroxide of hydrogen by measuring the evolved gas. Experience does not bear out this statement.

Early in the author's researches on the oxidation of the essential oils of plants, there was occasion to compare the properties of peroxide of hydrogen with some of the products obtained in the experiments, and it was then found* that not only might dilute solutions of peroxide of hydrogen be boiled for some minutes without any appreciable decomposition, but that the presence of chloride of zinc in quantity did not increase the amount of change. Mr. George E. Davis has since obtained similar results,† and finds that a

* *Journ. Chem. Soc.*, June 1874, p. 14.

† *Chem. News*, vol. xxxix., p. 221.

dilute solution may be concentrated, by evaporation, to half its bulk without driving off more than two-thirds of its active oxygen.

To illustrate the rate of decomposition of solutions as kept in the laboratory, Mr. Davis's figures may be quoted. The solution he operated upon was what is known as a "10-volume" one; that is to say, a solution capable of evolving ten times its own volume of gaseous oxygen when fully decomposed. Thus, 100cc. would evolve 1000cc. oxygen; in other words, it would contain 3·04 per cent. by weight, of peroxide of hydrogen (H_2O_2), and evolve 1·43 per cent. oxygen by weight:—

On August	2nd,	1878,	the	strength	of	the solution was 9	volumes.
,,	9th,	,,	,,	,,	,,	8·4	,,
,,	24th,	,,	,,	,,	,,	8·0	,,
Sept.	1st,	,,	,,	,,	,,	7·9	,,
,,	24th,	,,	,,	,,	,,	7·8	,,
Oct.	24th,	,,	,,	,,	,,	7·2	,,

By adding a few drops of ether, this strength was maintained, for on testing two months later it was found to be the same as on October 24th.

Dilute solutions of peroxide of hydrogen, then, are tolerably stable, and particularly if they be of slightly acid reaction; if, however, they be alkaline, owing to the presence of traces of soda, potash, or ammonia, then they are much less stable, and particularly evince a tendency to decompose entirely on heating. An alkaline solution of peroxide of hydrogen is partially decomposed by mere agitation, and the statement has been made that agitation with air is sufficient to entirely decompose even pure peroxide

of hydrogen in course of time. Mr. Davis does not corroborate this result, and, indeed, finds that by the passage of fifteen cubic feet of air per twenty-four hours through a dilute solution, no peroxide is destroyed; but on the other hand, he has found at the end of the experiment an excess, even in the presence of caustic soda.

Two facts in connection with this last named process may be cited with interest. One has been pointed out previously, viz., that of the apparently well ascertained production of peroxide of hydrogen or ozone by friction of waterdrops against atmospheric air. The other fact may have some connection, perhaps, with the possible behaviour of the caustic soda. Cuprous oxide (Cu_2O) shows no tendency to absorb oxygen and pass into cupric oxide (CuO) when it is suspended in water and subjected to a current of air. If, however, the water contains a very minute quantity of caustic soda, then it has been found that cupric oxide begins at once to form,* and goes on increasing until the whole of the red cuprous oxide is converted into the black higher oxide.

It is difficult to explain these facts, except on the supposition that caustic soda has the power, under the conditions given, to absorb oxygen, and pass temporarily into a higher state of oxidation. From this state it is immediately reduced to its former condition by the action of the cuprous oxide, which seizes its excess of loosely-combined oxygen for itself. No more attention can here be given

* *Chem. News*, January 5th, 1872.

to this subject, except to remark that, in common with many similarly interesting instances of slow oxidation, it calls for much further study and observation before an absolutely satisfactory explanation can be obtained.

There are several methods by which the strength of pure peroxide of hydrogen may be determined.

1. A given volume is taken and placed in a tube with excess of potassic bichromate; on agitation over mercury a volume of oxygen gas is evolved, which, supposing 1cc. of the peroxide of hydrogen has been taken, expresses its strength in so many volumes. Thus 1cc. of a 10-volume solution would yield 10cc. of oxygen at 0°C. and 760 mm.*

2. A given volume of the peroxide is treated in a measured tube over mercury, with excess of acidified solution of permanganate of potassium, when oxygen gas is instantly evolved, according to the equation:—

$$Mn_2O_7 + 5H_2O_2 = 2MnO + 5H_2O + 5O_2.$$

It will be seen from this equation that only one-half of the evolved oxygen is derived from the peroxide of hydrogen; and if this quantity be corrected for

* Peroxide of hydrogen furnishes a beautiful reaction with chromic acid, which first of all gives a blue colour with the peroxide of hydrogen; the oxygen is then gradually evolved, the colour fading at the same time:—

$$2CrO_3 + 3H_2O_2 = Cr_2O_3 + 3H_2O + 3O_2.$$

If an excess of peroxide of hydrogen be used in this experiment, then a further reaction occurs, in which the H_2O_2 loses exactly double the amount of oxygen lost by the chromic acid, so that the ultimate result is—

$$2CrO_3 + 6H_2O_2 = Cr_2O_3 + 6H_2O + O_6.$$

temperature and pressure, it agrees with the result furnished by the next method.*

3. When peroxide of hydrogen is added to a solution of potassic iodide (preferably acidulated with pure dilute sulphuric or acetic acid), there is a liberation of iodine, which is revealed by the red colour acquired by the solution. The ultimate result of the reaction may be expressed thus :—

$$2KI + H_2SO_4 + H_2O_2 = K_2SO_4 + 2H_2O + I_2.$$

If starch be added to the mixture, the free iodine combines with it to form a splendid blue compound, which by its depth of tint serves to render the determination of the iodine more accurate. This estimation is effected by ascertaining how much hyposulphite of sodium of known strength is required to decolourize the solution thus :—

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6.$$

Before passing on to other considerations, it must be stated that the action of peroxide of hydrogen upon potassic iodide is by no means instantaneous in kind. A certain amount of decomposition occurs at once ; but the rest of the decomposition is effected only very slowly, so that often half-an-hour or more is required for its completion. The process is therefore tedious, and for most purposes the second method is preferable.

* In illustration of both methods I have given examples in my paper published in *Journ. Chem. Soc.*, March 1875 (p. 9 of paper), but I have lately obtained results showing that it is best to employ a neutral solution of potassic permanganate in the second method.—Author.

The other reactions of peroxide of hydrogen are both interesting and numerous; but attention will be confined, in this place, to the more important ones only.

It bleaches litmus and many other vegetable colours, and in recent years has been largely employed for bleaching human hair, to which it imparts a golden hue.

It oxidises sulphides, and thus converts black sulphide of lead into the white sulphate:—

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

It is decomposed by many metals when these are presented to it in a state of fine division: gold, silver, and platinum, all occasion its decomposition in this way without being themselves thereby apparently influenced. This kind of action is well known in chemistry as contact action, but it is at present without a satisfactory explanation.

The oxides of the three metals just named also decompose peroxide of hydrogen; and not only this, but they are themselves thereby reduced to the metallic state. If the peroxide, in a very concentrated state, be allowed to fall, say, upon argentic oxide, this double decomposition is attended with explosive violence, owing to the rapidity with which the large volume of oxygen is liberated, thus:—

$$Ag_2O + H_2O_2 = 2Ag + H_2O + O_2.$$

The peroxide of hydrogen, as we have seen, unless specially protected against such an occurrence, gradually undergoes spontaneous decomposition from the

moment of its formation, and immediately that it comes in contact with bodies like argentic oxide, it gives a similar impulse to their molecular constituents, with the consequence of double and accelerated decomposition.

Brodie explained this fact by assuming that the second atom of oxygen in the hydric peroxide exists in a polar condition different from that of the oxygen in the oxide of silver; consequently, one being negative and the other positive, they exert a mutual tendency to combination, thereby forming a neutral molecule of oxygen.

All such actions and reactions may be explained in a general way which assumes nothing, while it suffices as an explanation. It is this. All substances, as we know and recognise them, exist by virtue of certain fixed conditions; and the more easily these conditions can be influenced from without, the more easily do such substances undergo change. In brief, mechanical, chemical, or any other kind of motion, exerts an influence on the powers which determine the state of a body.

Peroxide of hydrogen is not alone decomposed by metals and their oxides, but by almost every substance which admits of being oxidised. Thus ferrous sulphate is oxidised to ferric sulphate, and sulphuretted hydrogen is decomposed as follows:—

$$H_2O_2 + H_2S = 2H_2O + S.$$

That is to say, water is formed and sulphur is deposited.

Again, all animal and vegetable substances in a state of change or decomposition are rapidly acted upon by peroxide of hydrogen, much more vigorously, indeed, than by ordinary air or even pure oxygen; and hereafter we shall see what an important part it plays as a natural disinfectant. Curiously enough, it not only exercises a disinfecting action by virtue of its powers to give up oxygen to decomposing matters, but it can absolutely arrest decompositions under conditions to be named hereafter.

CHAPTER III.

THE PROCESSES OF OXIDATION, SLOW COMBUSTION OR DECAY, AND PUTREFACTION.

IN a previous chapter it has been pointed out that the processes of respiration and combustion may be regarded as identical in kind, both being of the nature of oxidation. It will be necessary, here, to define this latter process somewhat more fully, and to follow out its natural history.

Oxidation, then, may be said to occur when one substance gives up oxygen to a second one, and the substance which receives the oxygen is said to undergo oxidation; in other words, it is oxidised.

In burning, charcoal derives oxygen from the atmosphere; it is oxidised, and the product of the combustion is carbonic anhydride, thus:—

$$C + O_2 = CO_2.$$

If a jet of hydrogen gas be inflamed in an atmosphere of air or oxygen, oxidation also occurs, and water is produced, thus:—

$$2H + O = H_2O.$$

Again, if any hydrocarbon, such as benzene or tur-

pentine, be burnt in contact with sufficient air or oxygen, it undergoes oxidation, and yields water and carbonic acid gas as the ultimate result. For instance :—

$$C_6H_6 + 15O = 6CO_2 + 3H_2O,$$
$$\text{and } C_{10}H_{16} + 28O = 10CO_2 + 8H_2O.$$

In the same kind of manner every organic substance which exists in nature or can be produced in the laboratory, is amenable to this process of combustion. It is only necessary to properly mix the substance with something capable of giving up oxygen at the temperature employed, or to subject the substance to a current of air or oxygen at a suitable temperature, to decompose it by the act of oxidation which always results in the production of carbonic acid and water.

Of course, substances like sugar, which contain some oxygen as a constituent, require relatively less oxygen to burn them than they otherwise would, since the self-contained oxygen serves, in a measure, to consummate the process; thus sugar in burning oxidises as here represented :—

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O.$$

It is seen, that if the sugar contained no oxygen itself, its carbon and hydrogen would require 18 atoms of extraneous oxygen for perfect combustion, instead of 12, as is the case.

Even with carbon compounds of the greatest complexity, as also with organised matters, the law

of combustion holds good. For instance, albumin—which contains besides carbon and hydrogen; nitrogen, sulphur, and oxygen—is during combustion similarly decomposed. The carbon forms carbonic anhydride; the hydrogen forms water; the sulphur forms sulphurous anhydride (SO_2), (an oxide of sulphur), and finally sulphuric acid; the nitrogen is also oxidised.

These, then, are the changes which organic compounds undergo when burnt or combusted in air or oxygen.

Respiration is also combustion at a lower temperature; and in this process a number of carbon compounds, or waste products of the living body, are, in the blood, converted by oxidation into carbonic anhydride and water, which are finally given out in the breath. It must be observed, however, that this process does not take place with the living matter of the body, or, at least, it has not been proved to take place therewith.

The actual process of physiological combustion is one about which there is a deal of dispute. While Carl Voit* insists that oxidation in the body results as a consequence of tissue decomposition, and forms products by the combination of the inspired oxygen with the substances resulting from tissue change, other physiologists, such as Hoppe-Seyler,† maintain that the combustion of albuminous matters in the organism takes place in the living cells of the

* *Zeitschrift für Biologie*, viii., 297-388.

† *Pflügers Archiv.*, vii., 399-428.

tissues, and not in the lymph in which they are bathed, or in the blood, as held by some.

The bulk of evidence seems to be in favour of Voit's opinion, that the primary cause of tissue change is due either to ferments or some inherent cause which results in the production of certain proximate products of change, and that these being liberated into the juices of the body, combine with the oxygen there presented to them.

However this is, it may be accepted as generally true that, no organised substance, whether it forms part of a vegetable or an animal, is subject to oxidation, while it is controlled by the vital principle. But, apart from the component parts of living tissues, there is no organised substance which can resist the process of oxidation as it is carried on in nature.

While life lasts, organised substances are protected from ordinary chemical influences of the kind under consideration, by reason of the concatenation of forces which govern their molecules ; but when these combined forces are annihilated or sufficiently disturbed, death results, and the matter previously invincible by air and moisture now succumbs to their and other influences.

As respiration, although a rapid process of oxidation (seeing that 8·5 ozs. of carbon are daily oxidised in the body), is yet a slower one than that of ordinary combustion, so ordinary decay is very much slower than respiration. Nevertheless, it acts universally, and is omnipotent in its results.

In many places where mighty forests once stood,

and where the soil had been impregnated for ages with humus and loaded with vegetable substances, there can now be found no trace of organic remains. A few years suffice to clear the soil once occupied by the primeval forests of America, of organic matters.

Under ordinary conditions, humus slowly decomposes, and the carbonic anhydride and other products, are absorbed by the roots and other parts of plants, and converted into starch, gum, sugar, etc.; but if the plant life be cleared away, then the access of air to the soil is facilitated, and the molecules of organic matter are rapidly acted upon by the air and moisture, and leave the soil as carbonic anhydride and water.

The same process of slow oxidation occurs in cemeteries, where the dead bodies are gradually burned up, leaving only their mineral parts behind in the earth.

Naturally, there are conditions which specially favour this process, as well as others which militate against it. Eremacausis (as Liebig termed it) proceeds most favourably in the presence of water, and at a slightly elevated temperature. On the other hand, if the access of air be limited, the process goes on but slowly. Accordingly, it is found that, under such conditions, or where the air has been entirely precluded, organic remains may exist for a very long time. For instance, as all the world knows, dead bodies are preserved to a large extent from decay by a method of embalming and wrapping, which keeps away the air and moisture so essential

to slow oxidation. Indeed, the very existence of a mummy is, in its way, the best proof that could be submitted of the power of slow decay.

This marvellous process of oxidation is of infinite importance. By its action, the remains of animal and vegetable life are converted into the carbonic acid and water which are so necessary for plant life, and this, in its turn, gives back to animal life the oxygen which is essential to it. Thus the round of nature's operations is complete, and life is continually and for ever being reproduced from the same original matter.

The process of natural decay does not complete itself in one direct step, and this it is very important to understand. That is to say, compounds of vegetable and animal origin are not, by mere contact with the air, resolved by one direct step into carbonic anhydride and moisture. This undoubtedly occurs in combustion,—at least, for all practical purposes, this may be assumed,—but it is otherwise with eremacausis. This is gradual, and if not always, then at least generally, it occurs in several steps or degrees.

In some cases the oxygen of the air so influences organic matter that, by its combination, two or three or more distinct substances result, and only one or all of these may be subject to a further degree of oxidation, and each may take a different time to fully undergo the process.

Again, a complex substance such as albumin (white of egg), may be split up, by certain influences (as

by hydration), into several distinct substances before the oxygen of the air exercises any action whatever. This, however, afterwards begins, and then continues its work upon the compounds presented to it.

To make this clearer, it may be stated that when white of egg or blood albumin is boiled in the laboratory with certain reagents, may-be under a little pressure or otherwise, then it is resolved into a number of distinct substances, but all of which undergo oxidation if they are now exposed to suitable influences, giving rise to quite a new series of substances; and these again can, by suitable means, be resolved finally into carbonic anhydride and water.*

No doubt, within the body (in respiration) and in nature, these conditions obtain, since within the body there are ferments, and in nature there are very low forms of life, both of which are of sufficient influence to split up, say, albumin into a number of proximate constituent principles before the air (or oxygen) has exerted any kind of influence.†

* Here, of course, for the sake of argument, we are only dealing with the hydrogen and carbon.

† Indeed, it appears from the life-long labours of Pasteur that the process of slow oxidation really depends upon the development of organisms in the interior or upon the surface of matters which are in process of decomposition, and that in the absence of such organisms slow oxidation or combustion cannot occur. Just as the acetification of wines or beer depends upon vegetable growths (such as *mycoderma vini*) which possess the property of exciting oxidation in the solutions into which they may be introduced, so all other processes of slow combustion depend upon similar causes; and here we get a glimpse of the inutility of using agents like carbolic acid

Now, whatever oxygen, as air, is capable of doing in nature, in the shape of harmless oxidation, ozone and peroxide of hydrogen are much better qualified to do. Whereas air is a mixture of gases containing only 21 per cent. oxygen, ozone is a dense form of this substance, being many times more active than even pure oxygen ; moreover, when strong enough, it is in all probability fatal to certain low forms of life, which, if not the actual causes, are yet very intimately concerned in causing putrefaction, etc. In support of this it may be mentioned that Prof. Tyndall found that when infusions of highly putrefactive matter were subjected to the action of ozone, they remained quite sterile, while the action of condensed air neither prevented their putrefaction, nor kept them free from germ life.

Peroxide of hydrogen also contains oxygen in a most powerful and active form : it can no sooner come into contact with oxidisable matters than it at

for the destruction of such vegetable ferments. For these ferments are ubiquitous, and have a great function ; it is their natural work to cause slow oxidation in refuse matters, that is to say, in matters of animal and vegetable origin ; and if we could by any possible means exterminate this branch of natural beings, we should interfere with the way which was originally created and intended to serve as a sanitary measure for human welfare. We may, however, rest assured that this is not possible. Putrefaction is quite a different process to slow oxidation. The germs which initiate putrefaction cannot exist in the presence of oxygen, and as we shall see hereafter, the chemical act which they perform is not one of oxidation, but only a splitting up by hydration.

See Schützenberger's work on "Fermentation," pp. 241-244. King & Co.

once gives up its oxygen to them, in not only a pure but also a nascent state; and be it remarked that this is, universally, the most active state of gases. Moreover, by its liquid form (its wetness, so to speak) it is particularly qualified to come readily into intimate contact with substances. It has also been shown that peroxide of hydrogen is either fatal to certain kinds of germ life (vibriones), or else arrests their influence, so that putrefaction cannot occur in animal or vegetable substances protected by it.

The probable influences of ozone and peroxide of hydrogen, so far as they concern sanitation, will be more fully discussed hereafter. Here it is sufficient to point out that, as compared with the atmosphere, and weight for weight, they act far more rapidly and powerfully as oxidants; and this very fact has a great deal to do with putrefaction and similar processes, as may at once be appreciated if we consider that, although some germs cannot live without oxygen, yet when presented to them in the form of ozone or peroxide of hydrogen, they are either killed, or else prevented from carrying out their normal functions in compounds of an animal or vegetable origin, while septic organisms certainly cannot exist in the presence of peroxide of hydrogen.

Not only so, but ozone and peroxide of hydrogen exhibit another and significant feature. To illustrate this. It has been already stated that there are degrees of oxidation. If turpentine be heated in contact with a stream of air, it suffers a change of a definite kind, but it is one which is

gradual, and, amongst other products, peroxide of hydrogen is produced; but if turpentine be heated with nitric acid (also an oxidant, only far more powerful than air) it suffers a radical and quick change, the whole of the oil disappears, and if continued sufficiently long, the process gives only carbonic acid and water as ultimate products. Now let us pass from turpentine to albumin. If this substance be exposed to the air, it softens; and by the united action of water and air, under the influence of ferments, undergoes a complex process termed putrefaction, which is attended with the production of a number of substances, some of which are known, and some of which are not known. In process of time, however, the putrefaction passes away, and oxidation proceeds further, until the whole of the mass is oxidised into ultimate products. But if the albumin, instead of being exposed merely to the air, be boiled with dilute nitric acid, the end result is reached in a period of time which is infinitely more brief than that occupied by the more natural process of destruction.

Ozone and peroxide of hydrogen being similarly stronger agents of oxidation than the air, although not destructive and caustic like nitric acid, also have the power of avoiding the putrefactive process to which allusion has been made; or if that process has already occurred, then, of burning up or oxidising the products which are of a noxious character. If now, it be reflected how much matter of animal and vegetable origin is given back to nature—and particularly among

human populations—for disposal in a way which shall restore their elementary matters to a useful purpose without the attendance of disease, we obtain an insight into the importance of the process of oxidation, and can see why, at particular times and in special places, peroxide of hydrogen and ozone, two substances generated naturally, should exercise particular and beneficial powers.

Putrefaction is a process of such vast importance, that it is necessary in this place to bestow upon it some little further special study.

In the first place, it may be remarked that the number of putrescible substances is not great, but they are universally distributed, derived, as they are, from every organised being. Indeed, putrescence is a property almost or quite exclusive to the albuminous substances of which the flesh of animals is mainly composed, and which also enter into the composition of vegetable principles. It is these very matters which are the easiest to succumb to decomposing influences. To understand this subject clearly, it must be borne in mind that no kind of substance has an inherent tendency to change except real living, germinal matter. No distinctly chemical substance has any tendency to change, although we often speak of certain substances being unstable, or having such a tendency. What is really intended is to express the fact that some matters are more sensitive to extraneous influences than others.

Albumin is a chemical substance which, like all other chemical substances, exists in virtue of certain

forces of combination between its constituent atoms; and by protecting it from outside attacks, it may be kept unchanged for an indefinite length of time, or eternally. But when it is exposed to ordinary air and the presence of water, it is open to the attacks of certain low forms of life, to which it becomes pabulum, and under their initial influence putrefaction sets in, and oxidation into ultimate products ends the process.

Liebig, himself, knew very well that if blood be protected from the air, it does not pass into putrefaction; but he was wrong in supposing that it was the air itself which caused the blood to putrefy in course of time. It is not the air, but something which is in the air, viz., germs, or minute forms of life, invisible to the naked eye under ordinary conditions, but which are known to form part of the vibrating motes to which a ray of light passing through a darkened chamber owes its visibility (*Tyndall*). That this is so has been well confirmed in some recent experiments of Prof. Lister, in which he demonstrated the fact that newly collected blood neither coagulates nor putrefies if care be taken while collecting it, to exclude the presence of this germinal matter contained in ordinary air. This may be done in several ways well known to scientific men. Air can be freed from its contained living matter either by heating it to a sufficiently high temperature to destroy the latter, or by filtering it through plugs of cotton wool, the meshes of which retain the germinal matter, etc.,etc.

Recent researches have shown that germ life is

ubiquitous, and embraces an immense variety of species, so that the atmosphere is ordinarily loaded with a large number of forms. Accepting, therefore, the views of Pasteur, who has devoted his life to such studies, and taking blood serum to illustrate a putrescible substance, putrefaction may be thus described :— One or more vibriones fall into the fluid, and by feeding in the medium which is suitable to their development, they propagate their species. Since they live upon the albumin which is in the serum, they thereby decompose it, splitting it up into a variety of products. Simultaneously, a film of bacteria, mucors, and mucidines forms on the surface, from the introduction of other germs. Now, the life act of the vibrione is the impulse requisite for the decomposition of the albumin,—for the initiation of putrefaction,—and it may be fairly compared with the power of the liver to prepare bile from the albumin presented to it in the blood. It is even conceivable, if not probable, that the vital function of the vibrione is one of hydration, that is, one which results in the same products, or some of them, as are obtained when albumin is boiled in the laboratory, say, with baryta water or dilute sulphuric acid.

Oxygen is fatal to such vibriones as here described, but being in the fluid, they are practically protected from its effects. On the other hand, the bacteria which grow on the surface of the serum require oxygen for their very existence, so that they excite and accelerate the slow combustion of the products generated by the initial impulse communicated by the vibriones to the

albumin. As a final result of these changes, it would appear that the vibriones and bacteria also die, and are oxidised with the rest of the matter.

Now, the particular forms of vibrione which thus induce putrefaction, and those other living germs by whose agency slow combustion is eventually carried out, are, apparently, quite harmless in themselves; since, being ubiquitous and freely inspired with the airand contained in the water we drink, no evil result is produced. Nevertheless, vibriones can convert serum of blood, which is perfectly harmless when fresh, into a poisonous mass. It has been shown by Panum and Burdon-Sanderson that putrilage, even when absolutely freed from every kind of germ life, yet contains a particulate matter which, if introduced into the blood system of animals, produces septicæmia.

The reader, to thoroughly appreciate the meaning of these facts, which have been ascertained with extreme care and with great precision, must keep his mind free, for the time, from all other considerations. Here a clear issue is presented: germ-life, harmless in itself, produces in the process of putrefaction a blood or septic poison. Whether this is the direct consequence of a vital act,—the septic poison thus resulting as a chemical product of the pabulum consumed,—or whether the organisms secrete a ferment which does all the chemical work, is not decided. Such a chemical ferment or secretion may possibly have for its function the preparation of the dead matter as pabulum for the organisms, just

as gastric juice prepares food for assimilation in the human body.*

In some following pages more particular attention will be paid to the subjects of germs and infectious disease.

In concluding this chapter it is only fair to indicate the great extent to which we are indebted to Pasteur for his masterly researches on putrefaction and fermentation. It is no exaggeration to say that we owe the larger part of our knowledge of these processes to his investigations. In 1863 he defined† putrefaction as a fermentative process induced and sustained by animal ferments of the genus *vibrio*. This definition received confirmation from Traube and Gscheidlen‡ (among many others) in 1874.

More recently, M. Pasteur has found it necessary to divide living organisms into two large classes, which he designates *ærobies* and *anærobies*. The first require for their growth the presence of oxygen; while the second can dispense with it entirely.

Thus, as has already been shown, septic vibriones are killed by free oxygen; and, indeed, putrefaction cannot be induced in a substance until certain other organisms (mucors) have first of all used up any oxygen which may be present. It was the author's privilege to confirm some of the general statements

* See Dr. Drysdale's Essay on the Germ Theories of Infectious Diseases, pp. 5 and 6.

† *Comptes Rendus*, lvi., 1189; *Jahresb. f. Chem.*, 1863, 579.

‡ *Dingl. Polyt. J.*, ccxxii., 352.

here referred to, by some special experiments recently contributed to the Chemical Society.*

Finally, it must be remembered that slow oxidation or eremacausis is a process which must be deemed to occur in nature apart from putrefaction, at least in most cases. The two processes are in essence quite distinct, and depend upon entirely different germs. At times, undoubtedly, putrefaction either precedes or progresses simultaneously with slow combustion. Sanitary science aims at preventing this. It cannot materially interfere with Nature's grand law of slow combustion; but it can, and does, aim at preventing putrefaction, together with all the evils that are apt to follow its course when that occurs in or near human habitations.

* Contributions to the History of Putrefaction, Part I., *Journ. Chem. Soc.*, January 1880.

CHAPTER IV.

INFECTANTS AND CONTAGIOUS DISEASES.

ONE of the most important facts to be gathered from history, is the liability of human beings to be attacked by diseases of an epidemic nature. History, from the earliest known times down to the present day, furnishes more than sufficient proof of this fact. The Sweating Sickness of 1485, as also the Black Plague of London (1499), may be cited in illustration.

It is recorded by Short, the historian, that in 1625 there was a mortality from plague, in London alone, of upwards of 36,000. Then, again, in the years from 1635 to 1636 there was a plague mortality in London of 14,000; while in the years from 1663 to 1665 there occurred in the same city, it is said, between 70,000 and 80,000 deaths.

In brief, from the year 1490 B.C., when 624,000 Israelites were destroyed by plague in the wilderness,* till the outbreak of plague in Astrakhan in the last year (1879), history teems with the records of wholesale destructions of mankind by diseases of an epidemic character.

* Numb. xi. *Josephus Antiq. Jews.*

The years 1878-79 furnish at least three instances of wholesale infection, viz., the miasmatic fever of Cyprus, which, according to reports, placed 25 per cent. of the British troops at that time stationed there, on the sick list; the yellow fever, which occasioned frightful ravages in Mexico; and the plague, which seems to have originated in Astrakhan, and which set all Europe in fear and trembling lest it should be carried westward.

Of one disease alone—viz., typhoid fever—it is on record that nearly 100,000 cases occur annually, and of these about 15 or 20 per cent. prove fatal!

If we consider these facts, and "the almost total impotence of medicine for direct cure, we may indeed consider this a question more for statesmen and governing bodies than for physicians. Nevertheless, it is necessary that the efforts of the former should be guided by such knowledge of the nature and causes of these diseases as the science of the day can afford. Nor is such knowledge less to be desired for the people in general, in order to counteract the baneful effects of ignorance and prejudice."*

With these facts before us, let us now endeavour to ascertain how far science is able to indicate the nature and causes of infectious diseases, together with the means of arresting or preventing them.

In the first place, then, (adopting Dr. Drysdale's classification), these diseases are naturally divided into three classes, viz., those which depend upon

* "The Germ Theories of Infectious Diseases," p. 1. By John Drysdale, M.D. London: Bailliere, Tindall, & Cox.

miasms pure and simple, and in which the poison originates outside the body—they are not contagious; the contagious diseases arising from contagions or specific excitants, which are reproduced upon or in the bodies of the sufferers; and miasmatic-contagious diseases, in which the contagion is not so readily transmitted from person to person, but which at the same time is, nevertheless, always derived from a prior case, the poison being carried in the secretions.

As examples of purely miasmatic disease, we may instance malarial fever and septicæmia. In the first of these it is supposed that under favourable conditions, as regards moisture and temperature, vegetable matter undergoes a putrefactive process, resulting in the formation of a specific poison, which, by its reception in the living body, produces either remittent or intermittent marsh fever. The disease known as septicæmia is really very similar to this in many respects. For at the outset, the poison itself is produced during the putrefaction of albuminous compounds; and this, when introduced into the blood-system, gives rise to the disease in question. It has already been pointed out (in last chapter) that the specific infectant (sepsin) of septicæmia is a non-living particulate substance.*

Both sepsin and the malarial poison are always generated outside the body itself, and neither disease

* Consult Dr. Burdon-Sanderson's papers contained in the Reports of the Medical Officer of the Privy Council, etc. No. 3, 1874, and No. 8, 1876.

is communicable from one person to another, in the ordinary sense of that expression.

Small-pox, measles, scarlet fever, plague, and glanders, etc., are members of the contagious class of diseases. They never originate spontaneously, so far as can be proved; but are always communicated from one person to another, the specific contagia upon which they depend being evolved from one person, and reproduced in the contaminated organism. In small-pox the virus is thrown off from the skin; in measles, from the mucous glands of the nose and air passages; in scarlet fever, by the glands of the throat in particular, and so forth. How virus being transplanted seeks to establish and reproduce itself, will be our study hereafter. For the moment it is sufficient to recognise the fact.

The miasmatic-contagious diseases, like the contagious diseases, also depend upon the contagia for their development; but it appears that the virus of any one disease belonging to this class may be carried in the secretions and is capable of undergoing development outside the body. Thus in typhoid, the contagion is elaborated by the glands of the intestines, and hence passes away with the fæces. In these it resides, and may-be partly developes, being ready at any future time to attack those persons who may expose themselves to its influence. Supposing that such infectious matter be not immediately altered or destroyed, its possibility for harm is unlimited; for as the fæces dry, its particles may be carried either into drinking water

or the atmosphere, and happy is the man who neither drinks the one nor breathes the other when so contaminated!

Now of late years there has sprung up anew in the minds of men a very old theory of disease, but which, to do the new science justice, until recent years had but a most insignificant basis. The theory in question was revived by Henle in 1840, and again in his *Rationelle Pathologie*, in 1853; and although since then the classical researches of Pasteur on Fermentation, and those of Tyndall and others on germ life, have added much to the data, the theory has undergone no material change. In 1840 Henle taught that "infection in contagious diseases is caused by living beings, and that scabies is to be regarded as the type of contagious diseases." * To this, Liebig replied that such an opinion was founded on the principle that like effects imply like causes, and he goes on to add, "This is the very principle which for centuries impeded the progress of natural science, and which, even in the present day, leads to so many errors."

Liebig did not deny the existence of parasitic diseases; indeed, he admitted most readily that there are many diseases which are caused by parasites which develop themselves in and upon the bodies of other animals, and live at the expense of the constituents of these bodies. Scabies (or the itch) is such a disease, and muscardine, a disease to which

* Henle, *Zeitschrift*, ii., 305, and Liebig's "Animal Chemistry," English edition, 1846, p. 210.

the silk-worm is liable, is of a similar nature. In truth, there is no lack of examples.

Liebig, however, maintained that excluding parasitic diseases, which naturally require no chemical or any other theory to explain their communication, the true contagious diseases depend upon perfectly distinct and different causes. He writes,* "The condition which determines in a second individual his liability to the contagion, is the presence in his body of a substance which, by itself, or by means of the vital force acting in the organism, offers no resistance to the cause of change in form or composition operating upon it. If this substance be a necessary constituent of the body, then the disease must be communicable to all persons; if it be an accidental constituent, then only those persons will be attacked by the disease in whom it is present in the proper quantity, and of the proper composition. The course of the disease is the destruction and removal of this substance; it is the establishment of of an equilibrium between the cause acting in the organism which determines the normal performance of its functions, and a foreign power by whose influence these functions are altered."

In brief, Liebig looked upon fermentation and the true contagious diseases as processes in which a substance in process of change imparts by virtue thereof, a disturbance to the equilibrium of the elements of other bodies. Beyond this general definition he did not attempt to define the nature of contagia, but

* Page 205 of his "Animal Chemistry."

merely stipulated that all contagia are not parasites. He adds,* "In the contagion of small-pox, of plague, of syphilis, of scarlet fever, of measles, of typhus, of yellow fever, of dysentery, of gangrene, of hydrophobia, the most conscientious observation has not been able to detect animals, or even organised beings at all, to which the powers of propagation could be ascribed."

Thirty or more years have elapsed since these words were written, and although many conscientious and untiring workers have laboured in these paths of investigation, to-day's science can give no better theory of contagion, or better indicate the manner in which contagion acts upon the living body.

The further consideration of this subject, it being one of great dimensions and scope, will be best treated by stating the chief established facts without any discussion, except of some salient features.

It has, then, been established by the researches of Pasteur in particular, and others in general, that the ordinary processes of fermentation are so many instances of a biological reaction manifesting itself as the result of a special force residing in organisms; or, in other words, fermentation is essentially "a correlative phenomenon of a vital act, beginning and ending with it."†

Indeed, a ferment such as yeast behaves towards

* *Ibid.*, p. 209.

† See Schützenberger's work on Fermentation, p. 39. H. S. King & Co., London.

a chemical substance such as sugar, just in the same kind of way that a parasite behaves towards the body on which it preys. The two phenomena are correlative and parallel.

As yeast splits up sugar (or rather seems to yield a secretion which does the chemical work), and lives upon it, reproducing itself, so also certain forms of germ life behave towards albuminous compounds as previously explained. The one phenomenon is called fermentation, the other is known as putrefaction.*

The germs which induce putrefaction are ubiquitous, and this is a fact which it will be important to bear in mind hereafter. All the water and air we drink and breathe ordinarily swarm with germs of the three natural groups of the lower fungi,† viz., the mould-fungi, the sprouting or yeast fungi, and the fissiparous fungi, or bacteria. These groups comprise a great variety of septic and alcoholic ferment-organisms and monads, and form part of the organic matter of the air, which amounts to one grain in 200,000 cubic inches in the case of purer country air, and to one grain in 8000 to 10,000 cubic inches of less pure town air (*Angus Smith*).

To understand the infinitesimal size of these organisms it may be mentioned that Naegeli has calculated each to weigh only the thirty thousand millionth of a milligram! "Consequently," writes Dr. Drysdale, "all animals and vegetables on the

* See the Author's paper, *Journ. Chem. Soc.*, January 1880.

† Stated by Dr. Drysdale, partly on the authority of Naegeli. See p. 24 of his essay.

face of the earth are continually receiving abundance of fungus-germs in the water essential to their existence. Thus, in the air we breathe, in all that we eat and drink, and touch, and lie on, we are continually exposed to the reception of germs. Accordingly, bacteria and various fungi and germs have been detected on all parts of the surface, and of the mucous passages open to the air, and in the organs communicating with the mucous membrane. They are found in myriads on the tongue and in the tartar of the teeth, in the nose and throat, and all through the alimentary canal into which countless myriads are continually poured with our food and drink. Even developed bacteria have been found in the liver and spleen, and in the blood of healthy animals in certain cases; but the germs or spores are diffused through the interstices of the tissues, where under favourable circumstances they may come to maturity, as bacteria are sometimes found in abscesses shut off from the air. They are found also in the perspiration of the axilla, the face, and other parts; also in the fluid of blisters raised artificially. Nay, even, they are found in seeds or ova; the pink mould has been found in the middle of a nut, and the *dactylium soyerium* in an unbroken egg. The cells of plants produce fungi, which fructify within them. In short, we may take it as established that the whole of the higher organisms are interpenetrated perpetually with the germs of the lower fungi, and these may even develop in small numbers without much disturbance of health."

It is to the action of such germ life that the germ theory attributes all the contagious diseases to which man is liable!

It will be seen that the very ubiquity of germs is the most telling argument against this theory, and it may be safely said that its upholders, in their zealous search for germs, and hoping to find them associated with infective inflammations and contagious fevers, have indeed found them everywhere—much to their discomfiture. If it were true that germs constitute contagium-vivum, then it would no longer surprise us that infectious disease is of common occurrence. On the other hand, it would devolve upon the germ-theorists to explain the escape of any one individual from such an all-pervading contagium.

Yet the truth is, in spite of all that has been said and written on the side of the germ theory, its very advocates admit that as far as typhus, scarlet-fever, small-pox, measles, and the rest of the contagious fevers are concerned, "their connection with pathogenic organisms is, as yet, a matter of pure inference" (*Roberts*).* Nay, more, it is scarcely a matter of inference; it is one of pure hypothesis. It must be obvious to all, that if contagious fevers are attributable to specific germs, then small-pox, scarlatina, and typhus should originate spontaneously, instead of which they seem to be entirely dependent upon previous cases. This is an insurmountable difficulty

* "Reports on the Life History of Contagion." By Dr. Braidwood and Mr. Vacher. Also Dr. Roberts' recent Manchester address, *British Medical Journal*, 1877.

to practitioners, but the theorists have invented a way out of it.

It is true that the constant presence of a particular species or genus of germ may be demonstrated in the case of certain diseases, but it is also true that the same observation may be made in cases where there is no disease.

The germ-theorists evade this difficulty by crediting certain of these low forms of life—not distinguishable by appearance or life history from others known to be harmless—with pathogenic powers. That is to say, they view them as physiologically distinct, without sufficient warrant for so doing.

Then again, the germ-theory will not hold water, since it is practically impossible to perform an inoculation experiment in which, with certainty, only one specific organism is employed, and that in a state free from any diseased secretion, or other matter which may possibly constitute the contagium itself.

It must be admitted, on the other hand, that there are one or two special diseases which, it is now often confidently asserted, and not without considerable reason, are caused by low organisms. To these a little attention must be devoted before we proceed to study another doctrine, which to us is of a more acceptable nature.

Dr. Obermeier, of Berlin, was the first to observe spiral organisms in the blood of patients suffering from relapsing fever, and since then the observation has been often repeated. The disease is not contagious in the ordinary sense of that word, but may

be communicated by inoculation with the blood of a patient, although only if the blood be taken during the paroxysmal periods, when spirilla are present; they are absent at the crises, etc. From this it is concluded that the spirilla constitue the infectant. It is said that ocular evidence of the germ in question is all but absent, and all attempts to cultivate the spirilla out of the body have failed. Whether, therefore, the disease is, after all, not communicated by some other constituent of the blood, is unascertained.

In 1855, Pollender discovered minute staff-shaped bacteria in the blood in cases of splenic fever. Since then it has been ascertained that they also exist in the spleen, the lymphatic glands, etc., etc. Cohn and Koch having devoted particular attention to this subject, they have concluded that *bacillus anthracis* is the true virus of the disease.

Here, again, the contagium is communicated by actual contact of the blood or other exudations of a diseased subject, but it is not communicated by placing animals in the closest proximity to the diseased ones; in short, there is no infection through the air. It is also to be observed that the infective power of the blood disappears on the appearance of putrefaction. It is not necessary to go through the life history of this bacterium; it will suffice to state that Koch seems to have proved beyond doubt that, in suitable nutriment, spores are formed, and these reproduce the rod-bacilli, which are then competent to produce splenic fever in living animals.

Whether, however, this result is actually brought about by the germs in question, or by anything accompanying them, is not quite clear. The test was a crucial one; but, as admitted by more than one well-known pathologist, there exists some reason to doubt whether Koch obtained the bacillus quite free from other possibly poisonous matter.* The reason is the greater since Professor Cohn could not distinguish *bacillus anthracis* from *bacillus subtilis* (of the butyric fermentation) in a morphological sense.

More recently, Klein, by an investigation of infectious pneumo-enteritis in the pig † (pig-typhoid, so called), came to the conclusion that this disease is caused by a microphyte admitting of artificial cultivation outside the body, and which, when so cultivated, even to the eighth generation, is capable of producing the original disease in a healthy pig. No one can question the extreme care and skill with which these experiments have been conducted; but at the same time there exists the doubt (as in splenic fever) as to whether the disease is really caused by the germ itself, or is owing to some product to which either it, or some secretion from it, gives rise.

To illustrate the meaning of this argument, it will be convenient to recall the facts concerned in septicæmia. In that disease the poison has been proved not to consist of germ matter, but of a non-living substance elaborated by germ matter in a

* See Dr. Drysdale's Essay, p. 16. Also my "Animal Chemistry," p. 438.

† Seventh Annual Report of the Local Government Board for 1877-78.

proper medium; and so similarly, for aught that is known, both splenic fever and pneumo-enteritis of the pig may be produced.

The position may be summed up in a few words.

If it be admitted that splenic fever and so-called pig-typhoid are directly caused by microphytes, then such diseases must be taken out of the class of ordinary contagious diseases, and be henceforth viewed as parasitic diseases, being placed side by side with scabies, fungous-foot, and the horrible disease caused by the *trichina spiralis* when introduced into the living body.

This is, however, questionable, and certainly not sufficiently established so far; hence the diseases in question may be viewed for the present side by side with septicæmia and malarial fever.

In truth, much that is known regarding the etiology of the ordinary infectious diseases is against the doctrine of a germ theory. If the germ theory were true, then we might expect to meet with large numbers of isolated cases of disease having little or no connection, since the germs supposed to constitute the causes are ubiquitous. But, as a matter of fact, observation seems to indicate that the infectants giving rise to any set of cases are derived from previous cases, and these again seem traceable to more anterior ones.*

* See "Typhoid Fever, its Cause and Extent in Melbourne." By William Thomson, F.R.C.S. On p. 325 he writes: "True parasites never forsake a host while it lives. Fever germs mature, multiply, and cease. This is a radically important difference."

Another study which, so far as it has been prosecuted, also tells against the germ theory, is that of the distribution of disease. It is not possible to enter into any detailed consideration of it* here, but it may be laid down as a general proposition, fairly established by Mr. Haviland, that disease has a geography. He finds that certain districts are store beds of particular infections, and he is able to trace a connection between such states and local conditions. Thus Cheshire and Lancashire show the greatest death rate of all the counties in England and Wales, from scarlet fever: "in them scarlet fever seems ever to be stored, ready at a moment's notice to be carried far and near." Then again, the Thames runs through a vast cancer-field; and there does not exist an important river in England or Wales, subject to seasonal floodings, that does not flow through high mortality districts.

These and similar facts brought forward by Mr. Haviland demonstrate that places exist where the local conditions are such as either originate or favour certain specific diseases. These conditions are no doubt very multifarious, and partly concern climatic influences, geological particulars, water supply, and so forth. Nevertheless, if the specific fevers were due to ubiquitous germs, then these germs should, of themselves, be able to institute disease

* See a paper by Alfred Haviland, M.R.C.S., Ed., in *Journal of Society of Arts*, vol. xxvii., p. 157; also his work on the Geography of Heart Disease, Cancer and Phthisis. Smith, Elder & Co.

pretty uniformly; but we see that this is in opposition to the observed facts.*

There is another theory of disease, to obtain a proper understanding of which it will be necessary first of all to explain a few fundamental facts taught by physiological science.

Microscopic examination of the structures and tissues of the living body reveals the presence of a matter termed by physiologists "protoplasm," or "bioplasm;" and it has been ascertained that all forms of animal and vegetable life are derived in the beginning from this substance. It is a living, moving, and growing transparent matter, which exists in every part of the body, and it has the power of taking up or assimilating lifeless material,—pabu-

* The Annual Reports of Dr. J. M. Cuningham, the Imperial Sanitary Commissioner of India, bear upon the subject under discussion. The fourteenth Report (see *Practitioner* for August 1879) treats of the prevailing doctrines as to the causes of cholera in their relation to sanitary improvements. The *Reporter* says, referring to the water theory of cholera: "As the very existence of the cholera germ has itself still to be established, as well as the opinion that it resides in the discharges, not only is the chain of argument imperfect, but every important link in it seems to be wanting. *Cholera almost invariably travels, not down, but up the great drainage channels of the country.*" And again: "The water theory errs in demanding a remedy for only one out of many sanitary defects. But cholera is to be dealt with on the same general principle as all other diseases, and this is, that every sanitary defect must be sought out, and, as far as possible, remedied. The cause of cholera—what governs its distribution, and its relative incidence in different places—is still as inscrutable as when the disease first appeared; but it is well known that when this cause or combination of causes is present, it is favoured by filth, overcrowding, and every other condition adverse to health. The practical work to be done is to remedy these conditions."

lum,—which it changes in such a way that its elements lose their inorganic nature, become organised, and form part of the living bioplasm. In other words, bioplasm feeds upon dead matter, and thereby grows, increasing its mass. As this proceeds, the mass of bioplasm divides and subdivides into multitudes of smaller parts, and each of these parts gradually assumes a definite form or structure.

It is in this way that at the birth of an animal, the different organs and parts of the fully developed body are formed. And while life lasts, every organ and part is sustained by the formation of new material by the same process. The blood conveys the nourishment, from which the bioplasm resident throughout the organism appropriates the proper elements, and converts them into matter like itself, and this afterwards assumes structural form; the newly organised tissue is attached to the parent tissue, replacing that which is destroyed by the act of life. That is to say, in life, the tissues are worn down or away, being resolved into products which are removed by the breath, sweat, urine, and fæces. Every thought and act wears out, in this manner, some part of the living body, which is repaired in the manner above set forth.

This grand fact, although long known in principle, has been largely proved in detail by the researches of Lionel Beale.* He has shown that bioplasm, occurring in every part of the living body,

* "Bioplasm," etc. By Lionel S. Beale, M.B., F.R.S. J. & A. Churchill. 1872.

is germinal matter possessed of a power of selection of elements from the pabulum supplied to it, by which it converts dead or lifeless matter into living matter. But all bioplasm must die; and by the death, or, in other words, by the specific changes which happen in it at certain stages, tissue results, and hair, skin, bone, nerve, and muscle, are produced.

Thus we see that every different part of the body has its own bioplasm, by the growth, division, and change of which, so many different types of matter or secretions are formed. All this is certain, and is true, not only of animal, but also vegetable life.

So long as these normal changes go on, the life of the animal or vegetable is normal, and the products of the change in the bioplasm are physiological in nature. But if the senormal changes be influenced extraneously, then other products—departures from the normal type—are formed, and these are pathological in nature.

Such ideas as these, although not so clearly perceived, perhaps, have existed for ages in the minds of thinking men, and Dr. Drysdale has directed attention to the fact* that, "in Fletcher's Pathology it is laid down more particularly that the exciting cause of all contagious diseases consists of diseased secretions thrown off by animals affected with the same disease; while miasms, or malarious poisons, consist in diseased secretions thrown off by vegetables in a state of disease." This amounts in substance to

* See p. 33 of his afore cited Essay.

what has just been stated regarding the normal and abnormal changes of bioplasm, and furnishes us with a theory of infectious disease at once more simple, apparently more natural, and perhaps more correct, than the so-called germ-theory proper.

Mucus and saliva, like all other substances formed in the body, are derived from bioplasm, and so also is the poison secreted by rattle-snakes; and yet the latter substance is poisonous to man. The precise manner of its poisonous action is not known, but it may be supposed that, containing of course as it does, its own bioplastic particles, these are enabled so to influence the development of bioplasm in the part affected, that a departure from the ordinary changes is effected, and the result is death. It is not, however, by such obvious outside influences alone that the normal secretions of the body are influenced. They are liable to be perverted or diseased by a great number of causes, some of which may be even of a mental origin, and thus the body itself becomes irritated and diseased. It is, then, surely natural to believe that, if this can take place in the body of one individual, the vitiated secretions which are thrown off from the body are also competent to graft themselves upon or in the bodies of others, and similarly influence them; and thus we get an explanation of the action of contagion.

To perceive all this clearly, it must be borne in mind that just as nerve and muscle grow from bioplasm, so also do the secretions generally; indeed, all living or growing matter necessarily depends upon

bioplasm ; hence, just as mucus, when examined under the microscope, reveals the presence of bioplasts (the particles of bioplasm), so also do diseased secretions similarly exhibit such particles. If, now, such vitiated thrown-off particles come into contact with another person, they have the power, by virtue of the bioplasm which is contained in them, of grafting themselves in or upon the body, and thus disease is communicated. This is the theory of Dr. Lionel Beale.*

Now as bioplasm, whether normal or diseased, may also be called germinal matter, since it is literally living matter, it may be allowable to speak of disease germs ; but if this be done, it should also be pointed out that by this expression it is not intended to imply parasitic organisms of definite morphological characters. Such organisms are not comparable with bioplasm, for they themselves grow and develop by means of their own bioplasm, and hence they are only comparable in this sense with other organisms possessing structure, such as man. Bioplasm has no structure.

Since, however, the public at large have been misguided in the use of the word "germs," it is far better to speak of the "graft theory of disease," which clearly defines itself, while it has little in common with the parasitic theory of disease.

In the face of what has just been described, it is

* See Beale's work on "Disease Germs : and on the Treatment of Diseases caused by them." Also Dr. Ross's work on the "Graft Theory of Disease."

particularly interesting to turn back to the views maintained by Liebig against those scientific men of his day who advocated the parasitic theory. Liebig admitted the existence of vital force in a primary sense, and he maintained that (which to-day cannot be disputed) the life of an organism follows a determinated course, which results in a definite form and composition of the parts. While this process continues it is normal, and the result is health. If opposed by extraneous influences, the vital power of the organism resists them, or succumbs to them, according as to which is the more powerful process. Should the foreign power prevail, then the normal performance of function is interfered with, and the results are pathological.

It is seen that Liebig's teaching also establishes the individual power to resist disease, some persons being more susceptible than others, and thus succumbing more easily to its attacks. This individuality depends upon a great variety of conditions affecting personal history and surroundings.

In illustration of the graft theory of disease it will be instructive to mention a few facts.

In health, the clear, colourless fluid called mucus is a product of the transformation of the bioplasm of the mucous membranes; but floating about in it there are particles of living bioplasm which have been derived by division from the resident masses. Now if there be an excessive supply of nutriment, or if from some cause over-stimulation of the activity of the resident bioplasm results, then instead of

mucus being produced, an imperfectly elaborated, or degenerated, product is formed, viz., pus. In the same way as pus may take the place of mucus, so other parts of the organism may be similarly degraded, owing to the interference and influence of an extraneous power, and diseased products thereby result.

While health lasts, as already stated, every different tissue and part of the body grows from its own specific bioplasm; but pus is a fluid containing a common degraded form of bioplasm, or germinal matter, which goes on living and reproducing itself, but which cannot form tissue. It is common, in the sense that every kind of bioplasm may, by similar degradation, give rise to it.

Here we have a remarkable instance of the conversion of a living matter, which ordinarily would go to make tissue of some kind, into another living matter which has no power of forming tissue, but only the power to reproduce itself and to produce a fluid (pus), which is liable in itself to be both acrid and irritating, and which, when further changed as by the putrefactive process, can and does produce even fatal results.

Similarly, the specific contagia of the fevers and other infectious diseases may be degraded forms of bioplasm, which exhibit great powers of resistance (owing to their vital nature); they may be preserved in the moist or partially dry state, within certain limits, and when imperfectly desicated may be carried hither and thither by air or in water.

Without overstraining the analogy between ordinary infective processes, and the infective process of a cancerous growth, Dr. Creighton's investigations * of this last-named disease are of extreme interest, if viewed side by side with the graft theory.

Dr. Creighton has shown that cancerous diseases are characterised by the chronic self-propagative nature which they exhibit. When the elements of the originally diseased parts are carried by lymph or blood-streams to other parts, these latter are impregnated, and the tumour grows out of the original textural type. This result is not due to any specific organisms resident in the parent tumour, but rather to a ferment-like power of the transported elements which induces previously healthy parts to grow after the manner of the infectant.

These observations are vastly important, because it seems that in such studies the actual process of infection can be watched; and so far as at present determined, the process strictly accords with what might be expected to take place assuming that the secondary infection is due to the influence of degraded bioplasts derived from the primary growth.

Enough has been said to show the grounds upon which the graft theory of disease is founded; and it may be taken as well established that, just as one kind of plant or tree may be grafted on to another, by virtue of the living matter contained in the graft, so also graft bioplasts exist which are capable of

* Reports of the Medical Officer of the Privy Council. New series, No. 3, 1874, and No. 8, 1876.

attaching themselves and growing upon the previously healthy body, thereby producing a departure from the normal life history, or in other words, instituting disease.

The phenomena of infective processes are thus well explained; and if parasitic germs can and do produce disease also, it may possibly be that this is owing to their secretions rather than to themselves as living bodies preying upon the host. The bioplasm of the parasites may possibly create the disease, or the parasites may be the bearers of degraded bioplasm obtained elsewhere.

Of course it cannot be denied that evidence of an extensive and comprehensive nature is wanted; and until more facts are ascertained by strictly-conducted and accurate investigations and observations, we shall not make any material advance in our knowledge of the nature of infectious disease.

Writing of those diseases which now never arise except from infection, Dr. Drysdale says "their origin is hidden in the night of time;" and "although we may circumscribe the area of their operation, yet we can never hope that good food, virtue, drainage, and ventilation will extinguish them altogether, as long as man is a social animal."

Again, writing of another class of infectious diseases, —such as the catarrh and erysipelas group,—he says that as long as these "arise from the operation of mere common non-specific causes, if by any chance they were swept clean out of the land, they would infallibly reappear, so long as poverty, dirt, over-

crowding, famine, war, vice, etc., afflict the human race.

It has then been shown that there are :—

1. Diseases which are due to parasites.

2. Contagious diseases which depend perhaps upon graft-germs, or degraded forms of bioplasm.

3. Diseases which are due to mere chemical products, as is probably the case with the poisoning produced by sepsin.

Finally, it is seen that all these diseases originate from matters of an animal or vegetable origin, which may be directly derived from organisms by certain processes of change induced by degraded bioplasm or by microphytes (as in putrefaction).

And now having reviewed the various theories of disease, and the facts upon which they are based, to what conclusion are we impelled as regards the practical prevention of epidemics? The only conclusion points to the necessity of observing cleanliness of the body as of paramount importance with the health of the mind, and of securing pure air and pure water as also absolutely essential to sanitation.

While, however, the hope of ever extinguishing infectious disease is built upon a poor foundation, it must still be borne in mind that there exists a terribly large amount of actually preventible disease.*

* At the Sanitary Congress at Croydon, 1879, Professor Corfield said: "People who are living in the midst of general unsanitary conditions are in a worse plight than people living in the crater of an extinct volcano; for not only may any one of the severest epidemic diseases break out among them at any time, but they are continually sacrificing unnecessary victims to the demon filth."

There is no doubt that were the evacuations of typhoid-fever patients destroyed or properly treated in good time, there would be an end to, at least, a vast majority of the 100,000 cases that occur every year. Then, again, all the fever that owes its origin to well-pollution by drainage from the farmyard and its abominable heaps, is likewise preventible. Further, all miasmatic diseases due to the putrefaction and decay of vegetable matters are mere expressions of insanitary times, and could be largely avoided. While as regards such diseases as small-pox, scarlet fever, and the other members of the more contagious class of diseases, it is in human power to prevent also the majority of cases by a judicious circumscription of the area of disease in the application of strictly scientific methods.

In the next chapter an endeavour will be made to ascertain how far the use of antiseptics and disinfectants may help towards accomplishing such a desirable end as the prevention of epidemics.

CHAPTER V.

ANTISEPTICS AND DISINFECTANTS.

IF we possessed an accurate knowledge of the causes of infectious disease it would be an easy matter to specify the qualifications of antiseptics and disinfectants, but since our knowledge is most imperfect, it is very difficult to define those properties which, by their possession, entitle substances to be regarded as members of this class of reagents. Indeed, in a large degree, any such definition must, at present, be regarded as only approximately, however probably, correct.

Nevertheless, it has been shown in the last chapter that it is possible to arrive at certain general conclusions in the study of the causes and nature of infectious disease, and so by the application of these conclusions we are enabled to appreciate, in a corresponding measure, the right use of reagents which are intended either to prevent or arrest the spread of infection, and to induce and maintain sanitary conditions.

Indeed, all sanitary science, and a great part of preventive medicine, rests upon what is at present known about the subjects in question, and until

further research may yield more precise information this state of things must, of necessity, continue.

Of course, upon the view that contagious disease is caused by germs of definite morphological characters; that germ life, in fact, constitutes in itself contagium-vivum; it would seem at first blush that the best agents to employ for its destruction are those which are known to be fatal to life, or which have the power otherwise to arrest vital action. But it has been shown that such a view is not largely tenable, the contagious diseases being perhaps mainly, if not entirely, due to quite different causes.

Practically, then, those diseases which are undoubtedly due to parasites may be prevented from spreading, so far as this depends upon the mere transference of the parasites to other hosts, by the proper use of parasiticides, or, in other words, substances which are fatal to such living things. But the cure of any one case by the use of these agents is by no means a matter that can be guaranteed, the result of the method being evidently dependent upon the residential position of the parasites; for if they inhabit, say, the muscles or the blood, then the host would also be poisoned by the effectual use of substances intended to kill the parasites only. Hence, parasiticides can be merely applied to the surfaces of the infected body. Even in such a case, the cure is not certain, nor the non-transference of the infection to others guaranteed, since everything depends upon the killing-power of the parasiticide,

the quantity of which may be insufficient for the purpose, since the amount which can be used is necessarily limited.

The infectant, although it may be killed in one part of the body, may reappear in another part, and even affect outsiders, since, in the first place, the germ life, which under this theory is supposed to originate the disease, is apparently ubiquitous; and since, in the second place, in common with all living things, it exhibits very tenacious powers of resistance.

So that, as a matter of fact, parasiticides cannot be employed of sufficient strength to effect the purpose in view, without at the same time endangering, from their poisonous characters, the health of the public.

Putting aside, now, the parasitic theory of disease, and confining our attention to the strictly contagious diseases, such as small-pox, scarlet fever, typhoid fever, etc., etc., the difficulties found in the way of practical disinfection are of an equally pronounced nature. In these cases, the contagia are possibly degraded kinds of bioplasm, and, seeing we have no knowledge as to the specific influence of various chemical reagents upon such living matter, it is impossible to speculate, with any degree of certainty, upon the manner or measure in which the vital power of such infectants may be affected.

In connection with this subject, Claude Bernard has made some experiments which are of exceeding interest. He has shown that just as a man may be anæsthesiated by chloroform or ether, so also may germinating plants and low forms of

cell life be similarly influenced. Thus, the sensitive plant loses its irritability when placed in contact with the vapour of ether, but regains it when the ether is removed. Again, if the yeast plant be placed with sugar in etherised water, it will no longer act as a ferment. It is anæsthesiated, and cannot respond to the stimulus which, under ordinary circumstances, it finds in the presence of the sugar. Remove the ether from the mixture, however, and fermentation immediately sets in, and the sugar is resolved into alcohol and carbonic anhydride. In the same way, a disinfectant may act by anæsthesiating the bioplasmic particles which constitute infectants, rendering them powerless for evil, without actually killing them as parasiticides do.

There are many who think, with Drysdale, that probably the best means of protecting persons against such diseases as small-pox, will be found to consist in the extended art of vaccination, and that the most efficient treatment of other diseases, as ophthalmia, in the practice of inoculation. These, however, are matters which properly belong to medical science more exclusively, and do not concern us here.

Discouraging as is the present state of knowledge about these matters, there are some facts which, when properly studied, throw a real light upon the question, and these facts are those observed in relation to the process of putrefaction and its general connection with certain diseases.

It is a fact of universal observation, that the origin of epidemic diseases is often traceable to the putrefac-

tion of animal and vegetable matters. This has been observed for ages, and was particularly insisted upon even by Henle, who advocated the parasitic theory of disease.

Liebig attached great importance also to this fact, and directed attention to many observations,—all of them supporting the evident connection between putrefaction and certain diseases. Thus, he pointed out that miasmatic diseases are endemic in places where the decomposition of organic matter is constantly taking place, as in marshy districts, and that these diseases become almost surely epidemic when a marshy area is dried up by continued heat.

Besides this, it is known, with certainty, that some animal substances, in a state of decomposition, can excite a diseased action in the bodies of previously healthy persons.

This is often experienced in anatomical theatres; the slightest wounds made with instruments which have been used in dissecting putrefied bodies not rarely leading to dangerous and fatal results. In such cases, poisonous matter is communicated to the blood in the living body, and even in such infinitesimal amounts, is capable of producing the most terrible results.

Dr. Haviland, one of the most active and zealous medical officers of health, writes as follows:—* "Typhoid fever has no reason for existing at all, but whilst the porous soils of the sites of our villages are being polluted as they are, we must

* See his paper previously quoted on p. 79.

expect well-contamination and its sequel — fever One great source of well-pollution, which I have known to be the origin of much fever, is the farm-yard and its manure heaps. At present, the rural sanitary authorities are generally composed of farmers and others who cannot, or will not, see anything wrong in their barbarous muck heaps. The medical officer of health sees their effect daily. The effect of vegetable decomposition on the human system is varied, but marked. Let us take first the decomposition which produces ague and other forms of fever, as witnessed in the fen lands, the pontine marshes, and in other swampy grounds. Or remember the peculiar fever that is the result of living near the localities where flax is steeped and decomposed, or where indigo is allowed to ferment. Then, again, we must not forget that during the American civil war, some few years ago, a form of fever arose, simulating measles, which was traced to the decomposition of the straw on which the soldiers were bedded."

Attention has already been directed to the peculiar infectant which is contained in putrilage, and which Burdon Sanderson has shown to be of a particulate non-living nature. It is a most virulent blood-poison, and must, from the method of its production, inevitably attend as a product of the putrefaction of flesh wherever this may occur. This being the case, it is most probable that its formation also results from the putrefaction of other animal and vegetable matters containing albumin, since its production from flesh is traceable to the same chemical principle.

Sepsin, as this poisonous matter is termed, is a mere chemical product of change capable of exerting a physiological effect in the same manner as hundreds of other chemical substances exhibit peculiar physiological effects. Thus, the inhalation of chloroform produces insensibility to pain, and if taken in excess, results in death. Similarly, if a septic poison be received into the system, it will produce effects which, when recognised, are expressed as fever, and here again death may result, as in the case of chloroform.

It may also be borne in mind that many years ago Dr. Semmelweis established the fact, that a number of deaths occurred in a lying-in hospital at Vienna from the conveyance of putrescent matters to the genitals of the patients in an extraordinary manner. The physicians in attendance on the women were largely employed in dissecting, and it was known that these same operators would often leave the dissecting-room to examine women in labour, and thus introduce on their hands, the poisonous matter which led in so many cases to puerperal fever, and finally to death.*

It is true that the connection of all this with infectiveness is not quite so clear as might be wished; but we are left in no kind of doubt that at least many infectious diseases have their origin in putrefactive processes, and it may even be that sepsin is one sort of infectant. In any case, every medical practitioner and sanitarian is assured of the help which filth and

* See Appendix to Liebig's "Letters on Chemistry," p. 530. This instance is by no means singular.

insanitary processes give to contagious fevers. All maintain the vital importance of cleanliness, absence of putrefactive changes, and a good supply of fresh air and water.

Hence in sanitary science we aim at preventing putrefaction under given conditions, and the agents employed to prevent such processes are termed antiseptics. Indeed, an antiseptic may be defined as a substance which, when properly applied, prevents the formation of septic poisons in its vicinity. Such substances are not rarely termed disinfectants; and although this word is, as we have seen, not, perhaps, so correctly applicable, yet it is one in common use by the public, and therefore worthy of retention, unless it can be demonstrated to exercise a prejudicial influence by its employment. This cannot be done; and indeed it seems clear that if putrefactive change gives rise to infection, then agents which will either prevent or arrest this process may be fairly termed disinfectants.

Dr. Gamgee,* writing on this subject, says, "I am now convinced that every good antiseptic is really a destroyer of disease germs: an arrest of development is ensured."

It may, indeed, be taken for granted that the whole experience of the world in all ages goes to show that much contagious disease originates in the putrefaction of animal and vegetable matter going on in the midst of human habitations, and that the attempt to identify parasites with the causes of such disease is

* *Chem. News*, January 27th, 1871.

based, to a large extent, upon pure hypothesis. It has certainly been observed that the germ life which loads the atmosphere is instrumental in initiating and assisting putrefactive change; but it is not germ life which is in itself dangerous to the health of mankind; on the contrary, it would seem to be quite innocuous, the danger arising from the poisonous products to which putrefactive change gives rise.

From all this we perceive the importance of using antiseptic agents, capable of either entirely preventing such a process from occurring in our midst, or of so influencing matters that the poisons which would result under normal conditions are no longer formed. Such effects as these can be witnessed in the laboratory.

If a beefsteak placed in contact with air and water be allowed to putrefy, the resulting product constitutes a most virulent fever-producing product; but if we place with the beefsteak a certain quantity of antiseptic material, the putrefaction does not occur, and the poison is not formed. This is clear, and it is certain. Moreover, it is probable and almost certain that the poisonous matter in question, even if allowed to form, may be afterwards destroyed by certain other chemical substances which have the power of oxidising and burning it up, just as all the organic matter in nature is oxidised and burnt up under ordinary atmospheric influences.

With these facts before us it is possible to indicate the existence of at least three classes of substances, all of which are termed disinfectants.

First of all, there are the substances, like carbolic acid and thymol, which, being parasiticides, have the power, when present in sufficient quantity, of killing the living things (germs) which initiate putrefactive change.*

Secondly, there are other substances, like turpentine and camphor, which, while they exhibit a far less power of life-destruction, are yet capable of preventing putrefaction, possibly by diverting germ life from its normal actions in virtue of peculiar chemical or physiological effects.

Thirdly, there are substances which, if applied to putrefied matters, are capable of oxidising the effete matters, and of thus destroying the poisonous principles.

The permanganates of sodium and potassium and peroxide of hydrogen are illustrative of this latter class of substances, which may be said to exert the same kind of action as ordinary air, although more vigorously.

Thus, Mr. H. B. Condy says,† "Condy's fluid" (permanganate of potassium) "has in reality nothing in common with antiseptics. The disinfecting effects of alkaline permanganates are due not to antiseptic virtues, but to their oxidising powers." "In this respect they resemble free air." "This is the one by which ventilation acts as a disinfectant." He

* Prof. Wanklyn and others have recently raised doubt about the asserted disinfecting powers of carbolic acid, in spite of its powerful germicidal characters.

† *Chem. News*, January, vol. xxiii., p. 44.

further writes: "Carbolic acid is a deoxidating agent, which, when added to pure air, vitiates it, inasmuch as it behaves exactly like animal respiration, robbing the atmosphere of oxygen."

Dr. R. Angus Smith says, tersely enough, "We live in air, and the air flows continually into our blood: no wonder, then, that we are influenced by climate, which means the condition of the air."* Such a condition cannot be improved by the presence of poisonous and unwholesome substances, like carbolic and sulphurous acids.

Whatever value may be attached therefore to the use of poisonous substances like carbolic acid, it must be very limited in its nature, since, as shown elsewhere, the germs which they are intended to destroy are ubiquitous. So there can be no hope of their effectual destruction.†

* See "Air and Rain," p. 3.

† It is a favourite argument on the part of some that vaccine matter is to be regarded as the type of an infectant. I do not feel able to speak as to the accuracy of this view, since it appears to me that our knowledge of this matter is too limited; but it is of interest to point out that Dr. Dougall has shown carbolic acid to be of no practical use in destroying the infectiveness (if that term be admissible) of vaccinia. He writes (*Trans. Social Science Association*, 1874, p. 714): "I wish you particularly to bear in mind this simple but important truth,—namely, that the infecting property of a minim of vaccinia is unimpaired after being buried for thirty-six hours in the heart of a cubic foot of concentrated carbolic vapours."

Again, in the *British Medical Journal* of February 21st, 1874, occur the following words:—"It is stated in American medical journals that, so signal was the failure of carbolic acid as a preventive of yellow fever in New Orleans and Mobile, suspicion was awakened that its effect was positively injurious, and helped to spread the disease."

At the same time, it is most desirable to prevent putrefaction among the dwellings of men, while it is equally important to destroy putrefied matters where these may be found. Sanitary science aims at consummating these desirabilities, and it can only attain such an end by discovering and employing an agent which fulfils the purposes just sketched.

For universal use, it is essential that a disinfectant should be perfectly non-poisonous, non-inflammable, non-destructive to linen and furniture, and yield no stain; it is also desirable that it should be capable of deodorising, in which process it should not act by merely substituting one evil smell for the other: if, with all these properties, it should be healthful in itself, and useful for other purposes, such as preserving articles of food, etc., the agent in question approaches perfection.*

It cannot be insisted upon too strongly that, although carbolic acid is a powerful parasiticide and fungicide, this does not necessarily imply that it will destroy contagions, for, as we have seen, and as practical experience, in some instances at least, seems to bear out, most of the contagions are neither parasites nor fungi.—AUTHOR.

* The *Standard* of Wednesday, September 11th, 1878, in an excellent article treating of Disinfection and Disinfectants, pointed out in the following words those characters which fit a disinfectant for universal use:—

"Firstly, it should not be dangerous if by any chance it be taken internally, and we know that in the case of carbolic acid, for instance, fatal accidents from its use are of constant occurrence. Secondly, it should not be destructive of any substances to which it is applied, as such a quality would necessarily limit its action, and it could not be used, as noted above, to saturate sheets and cut off infection. Thirdly, it ought not to be offensive, for, even postulating the efficacy of an evil-smelling disinfectant, it is never likely to become popular, and

While the action of a parasiticide is well understood to consist in the actual poisoning of the parasite, the action of antiseptics (properly so-called) is one not so well understood. It must, however, consist in one of two things. Either they arrest, in some chemical or physiological manner, the normal activity and development of those vibriones which have the power to initiate putrefactive change, or else they so act upon the albuminous parts ordinarily liable to this change, that this liability is either lessened or altogether prevented.* It is easy, indeed,

it is to the general, we might almost say the universal, use of disinfectants that we must look for any permanent mitigation of the evil exhalations that so often pollute the atmosphere, and which almost invariably carry with them the germs of disease. Many disinfectants offered to the public fulfil one or two of these requirements; while others, though effectual enough, contain recognisable elements of danger. Only one or two may be used with confidence wherever a disinfectant is needed, always remembering that as the nation is reputed happiest which has no history, so that individual may be esteemed the most fortunate who manages so to purify his premises and order his household as to have no need to use a disinfectant at all."

Again, the *Daily Telegraph* of September 12th, 1879, commenting upon the death of a child poisoned with carbolic acid which had been used as a disinfectant, said, "Where the use is constant and regular there can be no doubt that the innocuous disinfectants, which are positively active generators of health as well as counteractives of disease, have the balance in their favour."

In a report recently issued by the National (U.S.) Board of Health, of which Prof. C. F. Chandler is Chairman, respecting the use of disinfectants, carbolic acid is cashiered altogether for a number of reasons, among which is that "it is liable by its strong odour to give a false sense of security."

* Peroxide of hydrogen acts in one of these ways. Pasteur has shown that vibriones (germs of animal life which induce putrefaction)

to conceive that both these influences are exerted, and the last-named one is of a kind often experienced in the chemical laboratory. The more complex substances are those most susceptible to decomposition. To put this in Liebig's words, "the larger the number of single elements and atoms which have united to form a group of atoms of definite properties, the more multifarious the directions of their attractions, the smaller must be the force of attraction between any given two or three of the atoms. They oppose to the causes of change in form or composition acting on them, such as heat and chemical affinity,* a far less resistance; they are far more easily altered and decomposed than substances of a less complex composition."

The albuminous compounds are particularly prone to these changes, which speedily take place when they are placed in contact with air and water. As already explained, it is not the mere contact of air and water which induces these changes, but these latter are due to the initial influences of vibriones usually present in air and water.

It is easily understood, then, having regard to the nature of those attractions which bind atom to atom

cannot sustain the presence of oxygen, nor therefore of peroxide of hydrogen. Its presence not only prevents putrefaction, but is fatal to any vibriones that may come within it.

Tannin would seem to act in the other way—viz., by combining with the putrescible albumenoids, thus forming inputrescible compounds, of which ordinary leather may be taken in illustration.—AUTHOR.

* The same is true of those causes which induce putrefaction.

in a compound, that many substances may behave as antiseptics and in very different ways. One antiseptic may act by entering into a sort of combination with the substance to be preserved, and thus strengthen it against all decomposing influences. Another may, by its mere presence, render the substance unfit pabulum for bacterial life; or again, it may itself serve as food to the germ life, and thus save the other material which would otherwise succumb to putrefactive change. In brief, every substance which tends to increase the resistance to change in matters susceptible of putrefaction, is an antiseptic and a disinfectant, no matter how it acts.

Enough has now been said in explanation of antiseptics and disinfectants, so far as the functions of such substances admit of explanation.

In a subsequent chapter the essential qualifications of disinfectants intended for universal use will be reproduced, with the view of testing how far one of these—which is produced in nature—fulfils its purposes.

CHAPTER VI.

MALARIAL FEVER AND THE EUCALYPTUS.

IN the two preceding chapters attention has been directed to the putrefactive changes to which animal and vegetable matters are subject, and it has been shown that these changes are intimately associated with the causes of infectious diseases.

It has also been shown that many contagious diseases have their origin in putrefactive processes, while certain miasmatic diseases are both endemic and epidemic in places where organic matters are constantly undergoing change, as is the case with marshy and damp districts. It will now be our object to illustrate this last-named statement a little more fully.

In his "Letters on Chemistry" (p. 230), Liebig says: "In no case may we so securely reckon on the occurrence of epidemic diseases as when a marshy surface has been dried up by continued heat, or when extensive inundations are followed by intense heat;" and in the Appendix to the same treatise there are recorded the following historical observations, which lend great weight to these views.

In constructing the railway from Strasburg to Basle, it was found necessary to excavate certain fields to a depth of two or three feet, thus causing a number of hollows in the neighbourhoods of Bollweiler and Feldkirch. In spring and autumn these hollows filled with water, and this partially drying up in the summer, created perfect morasses, abounding in the infusorial life characteristic of stagnant water. Thus, there was introduced intermittent fever into the neighbourhoods, and year after year the epidemic became worse and worse.

In 1843, of the 1446 inhabitants of Bollweiler, 36 were attacked with intermittent fever; 166 cases occurred in 1844; 743 in 1845; and 1166 in 1846. The mortality increased in a corresponding proportion.

Again, in 1843, of the 480 inhabitants of Feldkirch 2 were attacked with the same disease; 20 were attacked in 1844; 135 in 1845; and 376 in 1846; and the annual mortality rose from 11 to 18.

These particulars were augmented and confirmed by similar facts embodied by Drs. Weber, Sänger, and West in a report to the Prefect of the Upper Rhine.

Under these circumstances Dr. Dollfus-Ausset appealed to the Paris Academy of Sciences to use its influence and knowledge in instructing the administration, concerning the best means of checking the plague, which had already decimated two villages, and was then threatening others.*

* *Comptes Rendus*, Séance du 5th March, 1847, p. 779.

It does not, however, call for any such special cases to prove the source of malarial fevers. It is an observation which has grown with the world in age, that wherever there is matter of animal or vegetable origin in process of putrefactive change, danger to human health is also lurking in the water and floating in the surrounding air. It has already been explained that the mere rapid oxidation of organic matter is a comparatively innocuous process; and it is only when that normal process of change is substituted or accompanied by putrefaction that danger arises. The mere presence of organic matter in the soil does not necessarily indicate danger to the neighbourhood, because, supposing the soil to be of a porous nature, and in free contact with the air, the organic matter is very rapidly oxidised into innocent compounds—innocent compounds, that is to say, so far as infectious disease is concerned.

In writing of the effects of the surface of the soil on air, Dr. Angus Smith has these words:* "If soil affects the atmosphere, how does it happen that it is such an excellent disinfectant? Substances are not purified in the air to the same extent in the same time as in the soil. The great amount of surface in the porous soil is the cause of the rapid action mainly, but the acid humates act, and probably other substances, chemically. There are modes of oxidising in the air beyond the power of ordinary oxygen; one of these is by means of nitrogen oxides, and another by ozone; but even these require great

* "Air and Rain," p. 507.

time and space. If we throw sulphuretted hydrogen water or its compound with ammonia on a few inches of soil, it passes through, oxidised in a few minutes; we obtain such an action in the air only in great volumes, although in the end the work done may be better for its purpose." Nevertheless, it is possible to overload gravelly and porous soils, even those which oxidise the most rapidly. That is to say, it is possible, in a given case, to have more organic matter than, under existing circumstances, admits of oxidation in a certain time; putrefaction is the first result, and this may lead on to intermittent fever, or some other terrible disease.

Again, Dr. Angus Smith truly says* that "There seems to be a confusion in many minds between peat bogs and marshes, but the difference is very great. No peat-bog gives out marsh fevers and agues, although the cold and wet may induce rheumatism. The acid peat prevents decomposition, and so removes all the results of putrefaction, which some people suppose to be the origin of the evil in marshes."

The miasms of marshes, then, are matters which accompany the process of decomposition (putrefaction). Some persons—viz., those who accept the germ theory in its primary sense—regard the miasms as consisting of ultra-microscopical forms of animal or vegetable life; but facts have been already stated which appear to render this view unacceptable. Such forms of life may be mere accompaniments of the process of putrefaction, since the conditions of

* "Air and Rain," p. 520.

that process are also favourable to and indeed depend upon their growth and development; and, moreover, it is by every one accepted that where there is no such decomposition, there is no fever. Not only so, but there are marshy districts, which, as we shall see presently, are quite free from fever, although the forms of marsh vegetation, so far as these can be recognised, are all present.*

Having said so much by way of preface, we may

* Since writing this chapter there appeared in the *Practitioner* (for August 1879) a translation of a paper on Malaria, by Professor Klebs and Signor Tommasi-Crudeli. These investigators found that the malarial poison exists in quantity in the soil of malarious districts even at times when man is not affected with the disease, and that the poison may be detected at such times in the strata of air immediately above the soil. What is remarkable among the results of Klebs and Tommasi-Crudeli is, that they find large quantities of water render the germs inactive! It will be at once seen how this assertion stands in relation to the theory of the action of eucalyptus, which is disputed in the present treatise.

Klebs and Tommasi claim to have established malarial fever to be due to the action of *Bacillus Malariæ*, as they name the vegetable germ which they have obtained from the soil and air of malarial districts; but, in my opinion, this is by no means established. Their method of experiment consisted in subcutaneously injecting liquids obtained from the soil into animals, and noting the rise of temperature experienced. This was from the normal one to 41·8° C. Similar observations were made with the so-called artificially cultivated germs. The doubt attached to the interpretation of such experiments lies in this—that the subcutaneous injection of any solid matter would probably produce corresponding results. Even these investigators found that the fluid freed from the bacillus produced an intermittent increase of body temperature!

The bacillus is developed in the presence of free oxygen, and thus belongs to the *Aerobii* of Pasteur.

Then again, how was the germ rendered inactive by much water? By the poisonous principle passing into solution? —Author.

at once proceed to the more immediate purpose in view, viz., that of describing the power which is exercised by the *genus* eucalyptus of preventing and destroying marsh fever.

The *Eucalyptus globulus* was discovered* by Labillardière, in the Island of Tasmania, in 1792; but its fever-destroying characters first attracted the attention of M. Ramel in 1856. In this year he sent some of the seeds to Paris, and in later years forwarded further supplies, claiming for it, at the same time, the power of destroying the miasmatic influence of marshy districts. No doubt some considerable credit is also due to Baron Mueller (the Government botanist for Victoria), who originally brought the *Eucalyptus globulus* to the notice of M. Ramel; and a meed of praise is also merited by Sir W. Macarthen, of Camden, Sydney, Australia, who also exported some seeds in 1860, and claimed anti-miasmatic properties on behalf of the tree.

Since this now well-known tree was first brought before the notice of the public, its fame has been a rapidly increasing one, the evidence it its favour forming an almost unbroken chain down to the present time.

In a memoir by Prof. Gubler,† there is given particular testimony to the fact that this so-called

* See Professor Bentley's (1874) lecture on the Eucalyptus Glob, and his more recent one printed in the *Pharm. Journ.* for March 4th, 1878.

† *Journ. de Pharm. et de Chimie*, December 1871. (*Pharmaceutical Journal*, New Series, vol. ii., p. 703).

"fever tree," or "fever-destroying tree," exercises extraordinary effects in cases of intermittent fever. It is pointed out that, in marshy districts near eucalyptus forests the fever is practically unknown, and this state of things is attributed to the aromatic vapours which emanate from the tree, and the preservative powers of the branches and leaves which fall upon the marshy soils. It was upon the basis of this knowledge that the Algerian and Corsican plantations, of which more will be said hereafter, were made.

In 1871, M. Raveret-Wattel published a report * to La Société d'Acclimatation, in which he said: "Science is far from having said her last word respecting the part that may be played by these useful plants,"—meaning the eucalypti; and these words have since been verified in a singular manner. In his report, M. Raveret-Wattel specially dwells upon the importance which M. Ramel attached to the sanitary power of the eucalypti, and points out that this power was very much doubted when first it was claimed. He thinks, however,—and justly so,—that the plantations which were effected in the most unhealthy parts of Algeria have quite established the correctness of M. Ramel's views. The endemic fever in these districts was perfectly annihilated by the plantations in question; and the use of an infusion of the leaves of the tree, became so popular as a remedy against fever (even in many cases where quinine is said to have been administered with ill-success), that M. Alurmada had his trees completely

* *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

stripped of their bark by the populace. M. Raveret-Wattel adds that the oil of eucalyptus will no doubt become very useful as a remedy in putrid fevers, and for fœtid suppurations, etc.

In a paper contributed to the Californian Academy of Sciences,* in July 1872, by Mr. R. E. C. Stearns, the author quotes from a letter written by Dr. A. B. Stout, in which occur these words :—"There can be little doubt but that the oil of eucalyptus, when it can be procured, will be an available remedy against malarious diseases of all types, and that the presence of the trees cultivated in gardens, contributes to sanify the atmosphere from those emanations which give rise to epidemic diseases."

As already stated, the anti-miasmatic power of the grown-up eucalyptus was particularly tested in Algeria, and the results were communicated by M. Gimbert to the French Academy of Sciences.†

The report instanced the case of a farm situate twenty miles from Algiers, and notoriously known to possess a pestilential atmosphere, in which 13,000 trees were planted with the effect of absolutely stamping out the previously endemic fever.

A Dutch landed proprietor also planted a number of eucalyptus trees on the banks of the Scheldt, where he owned some property in a very malarious district. The effect was, that the particular spot was rendered quite salubrious, while the surrounding neighbourhood remained as fever-stricken as originally.

* *Western Lancet*, vol. i., p. 696. *Pharm. Journ.*, vol. iii., p. 603.

† See *Pharm. Journ.*, vol. iv., p. 494

A further and an interesting contribution to the history of the eucalyptus in Algeria was made a few years since,* to the pages of the *Pall Mall.* The writer points out that it was only so recently as 1867 that the Algerian plantations became at all extensive in character, and then he goes on to describe what he himself had witnessed but a few days prior to writing. He had visited the estates of M. Ramel, M. Trottier, and M. Cordier, whose trees had all been grown from seeds. On M. Trottier's estates at Hussein Dey, the trees were fifty feet high. "In this evergreen wood, all around us were tall reddish smooth stems, with the bark hanging down in a ragged, untidy manner,—for the tree sheds its bark in winter,—and grey, willow-like leaves were waving on flexible boughs. . . . It produced a curious impression to walk in the dim twilight of this Australian-African forest, and to think that this was also a wood of the miocene period. Beautiful is not the word I should apply to its appearance; but in exchange for bare sun-baked earth or deadly swamps, I must say these eucalyptus forests are most grateful, and the smell delightfully resinous, warm, and gummy. . . . There seemed to be a general impression that the eucalyptus was a fever-destroying tree, and of the greatest importance to the colony from that point of view." †

* *Pharm. Journ.*, vol iv., p. 731 (taken from the *Pall Mall*).

† I have not been able to obtain any reliable figures as to the distribution of the eucalyptus tree in various parts of the world, although from the text it is seen that it is now very widely distributed; plantations having been established all over the world. Thus, in

Mr. Bosisto, the well-known distiller of eucalyptus oils, has given some idea of the extent of area covered by eucalypti in Australia,* and its freedom from fever. He says, four-fifths of Australian vegetation consists of the eucalyptus; and that Australia, on the whole, may be said to be pretty free from violent endemic or miasmatic poisons. Concerning these latter, he further adds, "they might be said to exist only as the eucalyptus receded."

Now, in his report to the Commissioners of the Exhibition, Mr. Skene, writing of Victoria, states that the area of the whole colony amounts to 55,644,000 acres. Of this 5,560,000 acres are covered with dense mallee scrub; 6,225,000 acres consist of mountainous ranges, deeply wooded with gums; while the area of the open timbered country amounts to 38,922,000 acres. Upon the basis of these figures Mr. Bosisto calculates that the extent of mallee country in New South Wales and South Australia is twenty times that of the area in Victoria.

From these and other considerations, which will be dealt with presently, Mr. Bosisto concludes that the eucalyptus is established beyond all doubt as a fever-destroying tree.

Italy has also furnished its evidence upon this question. In a paper read before the Roman Aca-

Southern California, the *Eucalyptus globulus* is now planted by thousands; and it has been estimated that the gain in growing the timber is even a greater one than that derived from cereals.—AUTHOR.

* *Pharm. Journ.*, vol. v., p. 270, from a paper read by Mr. Bosisto before the Royal Society of Melbourne.

demy of Medicine, on April 30th, 1876, Dr. Fedeli * alleged that wherever plantations of the eucalyptus existed, malaria is unknown, and where the malaria has been endemic the cultivation of this tree suffices to mitigate in all cases, and in some instances to entirely remove, the disease. A long discussion followed the reading of Dr. Fedeli's paper as to the specific manner in which the eucalyptus exercises its powers; but while different views were taken of this question, the testimony borne to the febrifugal virtues of the eucalyptus was perfectly unanimous.

It is of interest to note that since the reading of Dr. Fedeli's paper, the Italian Government has supplied landholders with large quantities of slips of the tree for forming plantations in all malarious districts.

At a recent Easter Réunion at the Sorbonne, Dr. de Pietra Santra, a delegate from the Climatological Society of Algiers, recited some of the results of the investigations made in Algeria with the view of determining the value of the eucalyptus in its relation to public health. The reports received from fifty localities, boasting the possession of more than 1,000,000 trees, show, in the first place, that the eucalyptus exhibits a sanitary effect of the most unquestionable nature; secondly, that wherever the tree is cultivated, the intermittent fever decreases both in intensity and frequency; and lastly, that large tracts of marshy and uncultivated lands have been rendered healthy, and indeed quite transformed, by the agency

* *Pharm. Journ.*, vol. vi., p. 912.

of the eucalyptus. Dr. de Pietra Santra also showed that in Corsica, where more than 600,000 plants are growing, similar experiences have been obtained.

Between Nice and Monaco there existed, until recently, such a very unhealthy district, that the Paris, Lyons, and Mediterranean Railway Company were compelled to change their watchman who did service at a crossing in the neighbourhood, every few months. Some time since, however, a plantation of the *Eucalyptus globulus* was made there, and now there is said to be no more fever; and the necessity therefore for perpetual change of watchman (to prevent death) is abolished.*

There is yet one other instance † of the wonderful hygienic properties of the eucalyptus which may be mentioned here, although briefly. In a desolate part of the Campagna there stands an old monastic institution upon a spot consecrated by tradition as that whereon St. Paul was martyred. For centuries, this part of the Campagna was a stronghold of pestilential fever, and a residence in the monastic institution in question surely led to death. Some few years ago a band of Trappist monks planted the eucalyptus in its cloisters, and the trees are now more than thirty feet in height. What is more important, however, is that the place is now once more habitable, and fever reigns there no more.

That this effect is due to the eucalyptus plantation there can be but little doubt. It is true that the

* *Chem. News*, December 22nd, 1876, from *Le Mondes.*

† *Pharm. Journ.*, vol. vi., p. 624.

place was the execution-ground and burial-place for criminals of old Rome, and that 700 cart-loads of human bones have been removed. Moreover, the ground around has been deeply cultivated, thus assisting to make the spot habitable. But in spite of all this, and even if bones have been removed, it cannot be supposed that at this remote time from the days of old Rome, any organic substance forming part of the once buried bodies could have remained in the soil and have successfully resisted combustion by the atmosphere. Bones, themselves, are inorganic and harmless, and it would be more reasonable to look for malarial fever at Kensal Green than to search for it in an old Roman burial-ground, so far as it may be connected with the burials that have taken place at either locality. No doubt, the fever which once infested the Trappist Monastery at Tre Fontane, near Rome, has been overcome by general sanitary measures, but foremost among these was the cultivation of the eucalyptus tree.

All quarters of the globe have furnished evidence * of the sanitary value of the *Eucalyptus globulus;* and no one open to conviction can fairly withstand the conclusion that has been arrived at, after the study and experiments of the last half century, which is to the effect that the genus eucalyptus is both fever-preventing and fever-destroying. Any doubt, however, on this matter, will probably be removed by

* See also Consul Playfair's Report on the Febrile Virtues of the Eucalyptus, 1877.

the chemical evidence to be submitted subsequently.*

In addition to the direct evidence as to the hygienic importance of the eucalyptus already adduced, there is a certain large amount of indirect evidence leading to the same conclusion, and it is important enough to be briefly described in this place.

In his various papers, Dr. Gimbert of Cannes has directed attention to the fact that the oil of eucalyptus is not merely of a pleasant balsamic nature, but that it speedily removes all unpleasant odours. Moreover, he used the leaves largely, instead of lint, for dressing wounds, with very satisfactory results, and showed that when eucalyptus oil is mixed with albumin or fresh fibrin, putrefactive change is entirely prevented.

M. Gubler, also, has given testimony to the value of tinctures, infusions, and decoctions of the oil in surgery; and M. Mare used fresh young leaves to stimulate small wounds which were slow to cicatrize, and employed an aqueous infusion with great success in purulent catarrhal affections of the urethra and vagina. In consequence of these and similar observations, a large quantity of the alcoholic tincture of the leaves has been exported from Australia during late years for use in European countries.

Then again, Mr. Stearns has compared the disinfecting properties of oil of eucalyptus with those of

* According to recent reports, 50,000 eucalyptus trees are to be planted in Mexico as some kind of protection against yellow fever, and with the view of modifying the rainfall.—Author.

carbolic acid, and writes: "Its chief value, however, is as a sedative and antiseptic in asthma and throat diseases, nasal catarrhs, and affections of the mucous membranes." In his own investigations he used both the alcoholic tincture and the spray of the oil itself.

Dr. Gimbert found that the oil of eucalyptus and its various preparations diminish the vascular tension, and from inducement of a sense of comfort, tends to bring about sleep.

The success which attended the use of the same preparations in mitigating and curing ague, etc., led to the idea that the leaves of the eucalyptus contained some alkaloidal principle identical with, or similar to, quinine. This idea, however, was refuted by the experiments of Mr. Broughton, the Government chemist of Ootacamund, and later on by M. Rabuteau.* Mr. Broughton examined the leaves and bark, and states that neither quinine nor the other alkaloids of cinchona bark exist in the plant in any proportion. M. Rabuteau established the absence of all other alkaloids.

It is on record that in the Mauritius an infusion of the leaves of the eucalyptus was used with such great success in the treatment of malarial fever on one occasion, that the leaves were sold at sixpence each!

Another application of the eucalyptus was discovered in its effects upon rheumatic complaints: "Branches and leaves are put into hot water, and I am assured by those who have tried it that such baths remove rheumatic pains, neuralgia, and the

* *Comptes Rendus*, lxxv., 1431.

debility left by the malaria incidental to the country." *

Again, at a meeting of the Paris Société de Pharmacie, on Nov. 4th, 1874, M. Vidal communicated a note on the vermifugal characters of essence of eucalyptus when employed in the form of an enema, and gave the details of a case of a Zouave who was afflicted with the presence of a number of *oxyuris vermicularis*, which all ordinary vermifuges had failed to remove. It was completely cured in nine days by using each evening an enema containing from fifty to sixty drops of the oil to a quart. †

A watery infusion of eucalyptus leaves is known in France to be so useful in medicine and pharmacy, that it is now to be found in the French Pharmacopœia.

The mere preservative properties of oil of eucalyptus are well known; and since the date of the writer's earlier researches, they have been also investigated by Mr. T. Taylor.‡ He found that although the oil of eucalyptus is but sparingly soluble in water, yet such a solution has powerful antiseptic and deodorising powers, and is capable of considerably retarding certain fermentative changes and the putrefaction of albuminoids. He says: "The fleshy sides of the skins of animals may be preserved from putre-

* Quoted from the contribution to the *Pall Mall* previously referred to.

† *Pharm. Journ.*, vol. v., p. 474.

‡ *Ibid.*, January 12th, 1878, being an extract from the Report of the United States Commissioner of Agriculture.

faction by rubbing on them eucalyptus oil. It may also be combined with plaster and injected into the veins and arteries of animals for the purposes of preservation."

The anti-miasmatic power of eucalyptus and pine forests has been long supposed to have some connection with the volatile oils which are naturally secreted by them, and which find their way into the atmosphere. But in explanation of these results it has been generally held that the volatile oils in question, have the power, in some way, of giving rise to ozone—a substance which, judging from its chemical properties, may be supposed to oxidise, or burn up, the malarial matter infesting the atmosphere and soil of marshy districts.

Mr. Taylor thinks that the oxidant need not necessarily be ozone ; he is, however, quite satisfied that the oils of eucalyptus and turpentine, etc., do exhibit oxidising effects, and he quotes the author's experiments in support of this view. Some other more extensive experiments will be considered hereafter, and it will then be seen what truth there is in this view.

In connection with the salutary properties of eucalyptus forests, and before we attempt an explanation, it will be of interest to take notice of a few facts which have become matters of general experience ; facts which, known from very early times, have come down to posterity without any fair explanation.

For instance, it has been known for ages that the

atmosphere of pine forests is most favourable to invalids suffering from pulmonary affections; and even at the present time it is customary to send invalids to breathe the exhalations of the coniferæ. Such exhalations are generally, although quite erroneously, supposed to be strongly ozonised in character.

Dr. Cornelius Fox, in his very interesting work on Ozone, dwells also upon this subject, and alludes to the fact recorded by Herodian, that "in a plague which devastated Italy in the second century, strangers crowding into Rome were directed by the physicians to retreat to Laurentum, now San Lorenzo, that by a cooler atmosphere, and by *the odour of laurel*, they might escape the danger of infection."*

Referring also to certain investigations on the hygienic utility of essences and perfumes, about which we shall have something to say also hereafter, Dr. Fox says they "demonstrate that the disciples of Empedocles were not in error when they planted aromatic and balsamic herbs as preventives of pestilence." The investigations to which Dr. Fox is here referring were directed to the supposed production of ozone by the atmospheric oxidation of essential oils; and, continuing his observations upon this subject, he goes on to say that, "The ancient custom amongst physicians of furnishing the handles of their canes with vinaigrettes, the fumes of which might protect them from the noxious exhalations of their patients; and the old practice of strewing

* "Ozone," p. 121. By Dr. Cornelius Fox.

aromatic herbs, such as rue, before filthy prisoners in the dock of a criminal court, so that the olfactory nerves of the lawyers might be offended as little as possible; as well as that of providing the chaplain with a bouquet when accompanying a criminal to Tyburn, lose their absurdity under the light of these investigations. The efficacy of certain perfumes in warding off disease during exposure to fœtid air, which was thoroughly believed in by our ancestors, may be, perhaps, explained by the researches above referred to." *

We have then, again, the case of camphor, which from time immemorial has enjoyed a reputation as an antiseptic, and which is, to this day, worn by thousands of persons about their clothes as a protective against infectious diseases.

Lastly, the efficacy of wooden hospitals in inducing the rapid convalescence of patients has been supposed to be due — at least partly — to the resinous and turpentine-like substances existing in the wood, and which, by their evaporation into the atmosphere, pass, by way of the breath, into the patients' bodies.

Reviewing now the facts recited in the foregoing pages, we are presented with a mass of indisputable evidence, showing: firstly, that the eucalyptus tree both prevents and removes malarial fever; secondly, that the oil of eucalyptus also exhibits peculiar vermifugal, antiseptic, and disinfecting properties; thirdly, that pine forests exercise an important hygienic influence; fourthly, that turpentine, cam-

* "Ozone," p. 122.

phor, and other products generated naturally in pine forests, also exhibit certain properties which render them valuable as sanitary appliances.

Even if we allow a fair margin for any pardonable, but perhaps inevitable, exaggeration on the part of the different authorities whose investigations have been cited and referred to, and put down a certain number of results as doubtful, and some of the conclusions as erroneous, there yet remains abundant evidence of the hygienic value of eucalyptus and pine forests,* and a large amount of unquestionable testimony regarding the antiseptic, disinfecting, and healthful properties of certain products natural to these forests. And what is still more striking, there is an intimate relation between the hygienic value of

* Although slightly foreign to the object of this work, it is of interest to bear in mind that the sun-flower is stated to exhibit anti-malarial characters. The following paragraph in connection with this subject appeared in the *Pharm. Journ.*, November 29th, 1879 :—

"In a St. Petersburg weekly medical journal (quoted *Pharm. Zeit. f Russl.*, October 15th, p. 623), P. Filatow reports that in the provincial hospital of Ssaransk, during the last three years, an infusion of sun-flower (*Helianthus annuus*) has been used in numerous cases of intermittent fever, and in most of them with results as certain and satisfactory as those following the use of quinine. The 'infusion' used was prepared by digesting sun-flower stalks, cut into small pieces, during three or four days in eight parts of ordinary brandy; it is described as being then of the colour of sherry and tasting of sun-flower. The dose for adults was a table-spoonful three times a day, and the action is said to have been equally favourable whether administered before or during the paroxysm of fever. In fresh cases of fever the cure was completed in from one to three days, but in more confirmed ones, the use of the infusion required to be continued during a week or longer."

Perhaps the sun-flower yields also an essential oil which is volatile.

the pine and that of the eucalyptus; for both trees are healthful, and their products exhibiting similar properties, are also allied chemically. How far this resemblance holds good on further investigation, and the extent to which the hygienic properties of these trees is connected with the volatile oils furnished by them, will be fully studied and demonstrated in the ensuing chapters.

CHAPTER VII.

ESSENTIAL OILS AND THEIR ATMOSPHERIC OXIDATION IN NATURE, THE LABORATORY, AND THE WORKS.

IF we seek to establish the precise way in which the eucalyptus and the pine exert their hygienic influences, we are forced by exclusion to consider it in relation to the essential oils naturally formed in these trees, and to the emanation of which, in a vaporous condition, they owe their grateful fragrance. We may ignore in this place, the drainage power of the trees, because, although this is a valuable feature with them, it is one which does not concern the present considerations; and moreover, it is common to all trees, although particularly exhibited in those which, like the *Eucalyptus globulus*, grow so rapidly. Any sanitary effects due to mere drainage of water from the soil, is of a purely negative character; whereas the hygienic influences of the pine and eucalyptus are of a positive character. These trees are healthful in themselves, and the emanations which, speaking generally, they diffuse into the atmosphere, are specifically efficacious as regards protection from malarial poison and its destruction. What, then, is the nature of this influence? is the question that must now be solved.

It was for a long time supposed that the oils to which plants and flowers owe their perfume, when exposed to the action of atmospheric oxygen, influence it in such a way that ozone is produced; and hence it is stated, in most of the older treatises on Chemistry, as a fact that ozone is produced. It was beyond dispute that an active agent resembling ozone in its properties is formed in this way; but the precise and actual nature of this agent was (until established by the author's researches) entirely an open question.

There was a great difficulty, however, in strictly diagnosing ozone from peroxide of hydrogen; and as the last-named substance was practically unknown outside the laboratory, whereas ozone was known to occur naturally in the atmosphere, the assumption, which came to be regarded as an established fact, was somewhat excusable.

Schönbein, who was the great authority at that time upon ozone, thought that oil of turpentine gives rise to ozone by contact with air, and by-and-by others taught this as a fact, and thus it passed into the text-books. For instance, it is stated in Miller's "Elements of Chemistry," and Gmelin's Handbook. Lawes, Gilbert, and Pugh expressed their belief that the supposed ozone existing in the vicinity of vegetation is due to the oxidation of the hydrocarbons evolved by plants;* and in a paper communicated to the Royal Irish Academy on January 9th, 1871, Mr. C. R. Tichbourne, F.C.S., stated that when light

* *Journ. Chem. Soc.* (2), 1, 1863, p. 100.

resin oils are exposed to the action of the atmosphere under the influence of light, they produce an abundance of ozone, the boiling point of the oil being raised simultaneously. This last fact may be at once explained: the oil absorbs atmospheric oxygen, giving rise to the formation of oxidised compounds which boil at a higher temperature than the original hydrocarbons: peroxide of hydrogen and not ozone accompanies the reaction.

It is not surprising that the difficulties which Schönbein and Berthelot (who also examined the oxidation of oil of turpentine) could not overcome, should also have mislead others in more recent times.

Thus, Professor Paolo Mantegazza,* whose investigations were referred to in the last chapter, arrived at the conclusion that a large quantity of ozone is discharged by odoriferous flowers, including those of the narcissus, heliotrope, hyacinth, and mignonette. Similarly, he concluded that among plants, the cherry-laurel, clove, lavender, mint, lemon, and fennel produced ozone as well as the following perfumes: eau-de-cologne, oil of bergamot, extract of millefleurs, essence of lavender, and the oils of nutmeg, aniseed, thyme, peppermint, etc., etc.

In the well-known treatise on Inorganic Chemistry by Eliot and Storer,† there occur the following words: "The disinfecting power of ozone is interesting in connection with the observed facts, that ozone

* *Rendiconte del Reale Instituto Lombardo*, vol. iii., fasc vi.

† Second Edition, 1868, p. 145. Van Voorst, London.

is abundant in the air of pine forests, where turpentine abounds, and that pine forests are, as a general rule, remarkably free from malaria."

At the time when this treatise was written, chemists knew no better regarding the nature of the active principle engendered by the oxidation of turpentine. In 1878, however, and indeed long before, there existed better knowledge of the subject, and hence it is somewhat surprising that the old error should find its way into the generally excellent "Treatise on Chemistry" by Roscoe and Schorlemmer.* They, write: "Turpentine and several other essential oils, when acted upon by atmospheric oxygen, transform a portion of it into ozone,"—whereas they do nothing of the kind.

So also, Dr. Moffatt † has published a number of papers in which it is stated that he has found the oils of juniper and turpentine, etc., to produce ozone by contact with the air.

H. Fudakowski ‡ and E. Schaer,§ and numerous other chemists, have made the same mistake.

When the author commenced an examination of this subject about the summer of 1871, he was not acquainted with any of the publications of Dr. Day of Geelong; but late in 1875, and when he had arrived at and published his conclusions, these were brought to his notice. Dr. Day had made a

* Published in 1878. Second Edition, p. 200.

† See *Sanitary Record*, October 26th, 1877.

‡ *Deut. Chem. Ges. Ber.*, vi., 106-109.

§ *Ibid.*, vi., 406-410.

large number of very interesting observations upon various essential oils and certain fatty matters in which he had noticed the formation of an active agent resembling peroxide of hydrogen in its properties; but the tests which he employed to detect it are equally influenced by ozone; and moreover, as he seems in his papers, published prior to the author's, to speak of the substance not only as peroxide of hydrogen, but also as antozone (as if this were a distinct substance), his investigations did not materially advance our knowledge of the subject in question. It will be seen that the object which the author had in view was not only to establish the exact nature of the active principle, but the actual method of its formation. In this he was happily successful.

It may, however, be at once admitted that Dr. Day with great intelligence applied his knowledge to the explanation of the hygienic influence exerted by the eucalyptus, and also by wooden hospitals. While this is readily granted it must be understood that, after all, his experiments did not satisfactorily settle the vexed question as to whether ozone or peroxide of hydrogen is produced by the oxidation of the essential oils.

Moreover, in common with all others whose names have been mentioned in connection with the study of the hygienic influences of the pine and eucalyptus, Dr. Day totally ignored the formation of those organic compounds which have been since discovered to accompany peroxide of hydrogen as products of

oxidation, and to which the antiseptic powers of these trees is largely due.

With these preliminary observations it will now be of interest to describe the author's experiments in as simple a manner as the nature of the subject admits. Those scientific readers who wish to acquire a precise knowledge of the work can do so by consulting the references * given below.

Those plants which furnish essential oils in nature are very large in number, and comprise not only the members of the coniferous and aurantiaceous orders, but also the order *myrtacæ*. It is to the essential oils emitted by these plants at ordinary temperatures, or to products of their atmospheric oxidation, that their intense odour is due.

In the *umbelliferæ* the oil is most abundant in the seeds; in the *aurantiacæ* both fruits and flowers yield volatile oils; the *rosacæ* contain oil only in the petals, while the *myrtacæ* and the *labiatæ* supply it mainly from the leaves.

As is well known, many so-called essential or volatile oils, such as otto of roses, lemon, orange,

* "On the Oxidation of the Essential Oils. By C. T. Kingzett.

Part	i.	*Journ. Chem. Soc.*, Ser. 2, vol. xii., p. 511.	
,,	ii.	*Ibid.*,	,, xiii., p. 210.
,,	iii.	*Chemical News*,	,, xxxii., p. 138.
,,	iv.	*Ibid.*,	,, xxxiv., p. 127.
,,	v.	*Ibid.*,	,, xxxix., p. 279.

See also *Pharm. Journ.*, December 2nd, 1876; *Journ. Soc. Arts*, February 16th, 1877, and March 8th, 1878; *Brewers' Guardian*, September 18th, 1877; *Sanitary Record*, December 13th, 1878, and January 15th, 1880.

bergamot, etc., are prepared on a large scale for commercial purposes.

The essential oils mainly consist of hydrocarbons,—that is to say, substances exclusively composed of carbon and hydrogen,—and many of them contain also oxidised bodies which, at least in numerous instances, are formed from the hydrocarbons by the action of atmospheric oxygen and moisture. No doubt, many of the gums and resins which occur in nature are intimately related to the essential oils, and perhaps in some cases, indeed, derived from them.

Ordinary oil of turpentine, representing the hydrocarbon part of the essential oils of different kinds of pine-tree (*Pinus maritima*, *Pinus australis*, *Pinus Tæda*, etc., etc.), when analysed, is found to contain 88·23 per cent. of carbon, and 11·76 per cent. of hydrogen; and these figures lead to the chemical formula $C_{10}H_{16}$ as representing the constitution of turpentine. The mere analysis alone is not sufficient to fix this as the true formula; it might be C_5H_8, or $C_{15}H_{24}$, or $C_{20}H_{32}$, all of which substances would give the same percentage composition. There are, however, other considerations, of which we shall say more presently, which fix the true formula of oil of turpentine hydrocarbon as $C_{10}H_{16}$. This is called "terpene," in order to diagnose it from other substances which accompany it in the crude oil.

Similarly, other terpenes, or hydrocarbons of the same empirical formula, have been obtained from the oils of lemon, sweet orange, eucalyptus, bergamot,

lime, neroli, coriander, juniper, caraway, camomile, hop, parsley, wintergreen, thyme, valerian, copaiba, cubebs, birch, elemi, etc., etc.

There are other essential oils which, while they do not yield true terpenes, are yet intimately related to these substances. For instance, oil of cloves yields the hydrocarbon $C_{15}H_{24}$, oil of peppermint $C_{10}H_{18}$, and oil of roses $C_{10}H_{20}$.

Although the true terpenes are identical in composition, and are represented by the same formula, they yet comprise a certain number of distinct hydrocarbons; distinct, that is to say, in the sense that all their properties are not uniform, while some of them are common to all. The explanation of this is to be found in differences in the way in which the constituent atoms of the different terpene-molecules are arranged. Similar facts are known in inorganic chemistry, and are not at all uncommon. For instance, carbon exists in the form of the diamond and as coke, and other substances are capable of assuming various natural forms, although identical in mere matter.

A special property of all the terpenes consists in the avidity with which they absorb oxygen, either from the pure gas or from the atmosphere. In illustration of this fact, there are here reproduced two tables from papers of the writer published at different times. The oils in question were placed along with known quantities of air and oxygen, in tubes sealed at one end; and after exposure under various circumstances for given periods, the amount

of oxygen absorbed* was measured by ascertaining the remaining amounts.

Name of Oil.	Cubic centimetres of oxygen absorbed.	In No. of days.	= Daily.
Turpentine—			
(*a*) in sunshine	220 from oxygen gas	6	36·6
(*b*) in shade .	20 „ „ „	36	0·6
Caraway . .	18 „ „ „	6	3·0
Bergamot . .	12 „ „ „	4	3·0
Juniper . .	5 „ „ „	2	2·5
Cubebs . .	4 „ „ „	2	2·0
Lemon . .	16 „ „ „	13	1·2
Naphtha . .	25 „ „ „	33	0·7
Camomile . .	6 „ „ „	11	0·55
Turpentine (in shade) . .	10 „ air	14	0·75

The experiments recorded in the next table were conducted by charging a number of very long sealed tubes with equal volumes of air, oil, and water, and exposing them to summer sunlight for a few hours, and not sufficiently long for the whole of the atmospheric oxygen to be absorbed in any single instance. The residual, unabsorbed gas was afterwards measured in the laboratory. Calling the largest amount of oxygen absorbed 100, then—

1. Russian oil of turpentine absorbed 100
2. Swedish „ „ 100
3. Some oil which was obtained in Geneva, absorbed . 89·4
4. American oil of turpentine „ . . 78·9
5. Oil of eucalyptus „ . . 75·0
6. An evidently adulterated Swedish turpentine, absorbed 52·6
7. "Scotch-distilled American turpentine" „ 42·1

* Ether also absorbs oxygen, and forms peroxide of hydrogen. See Parts I. and IV. of the research.—Author.

The oils numbered 1, 2, 4, and 5 were undoubtedly genuine commercial oils; the oil 3 was, perhaps, French oil of turpentine, and in this case only was the sample rectified by distillation before making the experiment, since it had undergone great oxidation by keeping for many years. The oils 6 and 7 had been sent as samples, and were evidently not genuine; probably both had been largely adulterated with so-called pine-oil of commerce.

The absorption of oxygen (even from the atmosphere) by essential oils and the true chemical terpenes, takes place at the ordinary temperature, although, of course, it happens more slowly at a low than at an elevated one; more slowly therefore in winter than in summer; more slowly in shade than in direct sunlight; more slowly in the dark than in diffused daylight; and in all cases, even where pure oxygen is used instead of air, the products are identical so far as has been ascertained.

Now, if the pure hydrocarbons obtained from essential oils, be placed in contact with a mixed solution of iodide of potassium and starch, they will not colour this test * mixture at once, but only after standing some time exposed to the air. On the other hand, if the experiment be made with those hydrocarbons which have been previously allowed to absorb oxygen from the air, a colouration is produced at once. The potassic iodide is decomposed; iodine being set free, and this combining with starch, forms

* This mixture has been stated in a previous chapter to be a test for peroxide of hydrogen and ozone.

a blue compound, causing the colouration in question. Similarly, if the essential oils be exposed to the air in shallow vessels covered loosely with bibulous paper soaked in the same test mixture, the colouration is seen to take place, in time, upon the paper. That is to say, the oils evaporate slowly, and combining with atmospheric oxygen, produce the active principle, whatever it may be, which thus comes in contact with the test-paper and influences it. If the evaporation be assisted by placing the vessels upon a warm metallic plate, the reaction is obtained more speedily, and is more intense in character.

If instead of soaking the paper in the mixture above-named, it be moistened with acetate of lead, or sulphate of manganese, no colouration is then produced, nor are solutions of these respective substances coloured, even when placed in contact with the oils themselves, and on free exposure to the air. This result seems at once to indicate that the active agent is not ozone; for if it were, affirmative results would be obtained.

Moreover, Soret proved unmistakably that oil of turpentine readily absorbs ozone; it is therefore utterly improbable that a substance which absorbs ozone should also produce it under identical conditions.

After studying the influence of peroxide of manganese, peroxide of lead, and hyposulphite of sodium upon oxidised oils containing the active principle, and having observed that these substances totally destroyed it, a fact of an important nature was experienced.

The oils of turpentine and caraway were oxidised to a considerable extent; then washed with water to remove any peroxide of hydrogen,* and finally introduced into vaccuous bottles containing mixed potassic iodide and starch, when the blue colouration was at once produced. It having been proved that the active principle, as directly formed, could not be ozone, and as the method of experiment excluded the possibility of its identity with peroxide of hydrogen, this new fact admitted only of one explanation, which is as follows :—

The essential oils absorb oxygen from the air, and there is thus produced an additive product of an organic nature, exhibiting properties like those of ozone and peroxide of hydrogen ; in other words, an organic peroxide is produced.

By perfectly distinct methods, Sir B. C. Brodie and others had previously fully established the existence of such peroxides, and no doubt was felt but that the experiment in question also established the same fact in quite a new manner.

At the same time, it was observed that the active principle of oxidised oil of turpentine is entirely destroyed by heating it in contact with dry chloride of zinc to a temperature of 75°C.; whereas, in absence of the chloride of zinc, it was not affected by being heated to this point. Similarly, other dehydrating and deoxidising substances were found to destroy the active agent.

* It was subsequently ascertained that any peroxide of hydrogen either contained in, or attached to, the oxidised oils is entirely removed by washing them with water.

Having got so far, some steps were taken with the view of ascertaining more particularly the precise conditions upon which the formation of the active substance depends, and it was found that it forms whenever oil of turpentine (for example) is placed in contact with air only; that is to say, it was ascertained that the presence of water was not necessary.

It was noticed, however, at an early stage of the research, that the production of the active substance was much facilitated by carrying on the oxidation of the oil by means of a current of air, in the presence of water, at a slightly elevated temperature; and in order to obtain further information, great quantities of turpentine were oxidised in this way. It at first appeared strange to find that the water standing underneath the turpentine after these experiments, contained beyond question peroxide of hydrogen. With the potassic iodide and starch mixture it gave the blue colouration; with chromic and sulphuric acids it also gave the characteristic reaction wherein the violet perchromic acid is first produced, etc.; while it evolved oxygen gas when treated with an acids solution of permanganate of potassium. In brief, there were obtained aqueous solutions containing so much peroxide of hydrogen, as to be capable, when decomposed, of evolving twice their own volume of oxygen gas.

It was thus proved that in the oxidation of oil of turpentine neither ozone nor peroxide of hydrogen is directly produced, but that the active substance

which is first formed yields peroxide of hydrogen when treated with water. So that if the oxidation takes place originally in the presence of moisture, peroxide of hydrogen is found in the aqueous solution.

All these observations accorded with the conclusion that the oxidised compound first produced is an organic peroxide; and as Brodie had stated that when camphoric anhydride is heated with peroxide of barium, camphoric peroxide is produced, it seemed that the author's product might be this same substance. In such case, it might be supposed to be decomposed by contact with water as here represented :—

Camphoric peroxide + water = camphoric acid + peroxide of hydrogen.

$$C_{10}H_{14}O_4 + 2H_2O = C_{10}H_{16}O_4 + H_2O_2.$$

This idea was supported since, whatever may be its source, camphoric acid was found in the aqueous solution accompanying the peroxide of hydrogen, and some of its compounds were prepared and analysed. But whether the active organic compound be camphoric peroxide or not, it is, at any rate, decomposed slowly by contact with water, and the aqueous solution then contains peroxide of hydrogen, and camphoric, acetic and formic acids.

The great proof that peroxide of hydrogen only results as a product of secondary decomposition, was afforded by the observation that when the oil is oxidised in the absence of water, and afterwards agitated with large volumes of water, it still retains

its active properties, and yields more peroxide of hydrogen on further standing with water. The oxidised oil may even be dissolved in spirit and poured into water, and yet, after separation, retain some undecomposed organic peroxide. This may be well shown by placing it with potassic iodide and starch (in the presence of a suitable acid), and estimating the iodine thus set free by means of a standard solution of thiosulphite of sodium. If the oxidised oil contained mere peroxide of hydrogen in admixture, this latter substance would be entirely removed by simply shaking with water. This, however, is not the case. Moreover, if strongly oxidised oil of turpentine be placed in a retort and heated to 160°C. (the boiling point of pure turpentine), the temperature suddenly rises spontaneously, effervescence sets in, and oxygen gas pours out with the vapour of the boiling oil.

Being anxious to establish some kind of relation between the terpenes of turpentine and the other essential oils, as also to obtain some further explanation of the facts which had been discovered, the later method of experiment—viz., oxidation in presence of water by a current of air—was extended to various different substances. Those * examined at that time were :—

Cymene, $C_{10}H_{14}$ (from several different sources).
Hesperidene, $C_{10}H_{16}$ (the terpene of oil of orange-peel).
Myristicene, $C_{10}H_{16}$ („ „ „ „ nutmeg).
Menthene, $C_{10}H_{18}$ (from solid Japanese camphor).

* For some of these specimens I was indebted to Dr. Wright and Prof. Church.

Oil of wormwood (containing, according to Wright, much $C_{10}H_{16}O$, and a little terpene $C_{10}H_{16}$).
Oil of citronella (containing much $C_{10}H_{18}O$, and *no terpene*).
Yghlan Yhlang (containing no terpene).
Hydrocarbon from oil of cloves, being $C_{15}H_{24}$, as shown by Church.
Patchouli (containing no terpene).

The cymene from every source yielded peroxide of hydrogen in the aqueous solution, as did also all the terpenes as well as those oils which contained even the smallest quantity of terpenes; menthene ($C_{10}H_{18}$) behaved similarly. On the other hand, the hydrocarbon from oil of cloves ($C_{15}H_{24}$), and those oils which contained no terpene, gave no trace of peroxide of hydrogen.

From these and other experiments which need not be referred to in this place, two inferences may be made:—

1. That every essential oil (as ordinary turpentine), which contains a hydrocarbon represented by the formula $C_{10}H_{16}$, as also every pure terpene, gives peroxide of hydrogen when their oxidised products are treated with water.

2. That the production of peroxide of hydrogen in this way is related to cymene, for both Oppenheim and Wright have proved that cymene may be obtained from all the true terpenes ($C_{10}H_{16}$),* and it has been shown that cymene gives peroxide of hydrogen, while menthene gives both cymene and peroxide of hydrogen.

These conclusions were subsequently confirmed by

* Dr. Tilden has also shown that all terpenes yield the Nitroso derivative $C_{10}H_{15}(NO)$.

the observation made by Wright, that the $C_{15}H_{24}$ hydrocarbon from oil of cloves, which does not yield peroxide of hydrogen, fails to yield cymene when subjected to the process by which all true terpenes ($C_{10}H_{16}$) yield it.

Another confirmation was afforded by the experiments of Mr. M. M. Pattison Muir, F.R.S.E., who found * that oil of sage absorbs oxygen and produces peroxide of hydrogen. He afterwards showed that the oil contained a quantity of a terpene ($C_{10}H_{16}$).

Whatever worth, then, the above stated hypothesis may have, the fact is established beyond doubt, that all oils which contain cymene or terpene, such as those of eucalyptus and turpentine, give rise to the production of peroxide of hydrogen, when subjected to the process described in the foregoing pages.

To revert once more to the atmospheric oxidation of oil of turpentine. There are various kinds of this oil known to commerce, differing according to the species of tree from which they are obtained, and probably (to some extent) upon the climatic and geological conditions of the localities in which the trees are grown. Moreover, all turpentines are not alike in their power of absorbing oxygen, some absorbing it much more freely than others.

It has been further observed, in certain cases, that an oil of turpentine which absorbs oxygen from the air at any given rate, will absorb it much less rapidly if freed from accompanying oxidised substances, by distillation. In other words, when once the process

* *Year Book of Pharmacy*, 1876, p. 561; 1877, p. 498.

of oxidation has begun, it continues more and increasingly rapidly, so that the greater the amount of oxidised matter contained in the oil, the greater the oxidation under given conditions.

From these facts it may be inferred that in nature the process of oxidation, as occurring in the immediate surroundings of the trees themselves, takes place, in all probability, much more rapidly than in the laboratory; since, as produced in the trees, the oil is accompanied with the products of oxidation, to which reference is above made.

It is indeed remarkable that turpentine, in the act of being oxidised, is capable of imparting to fresh turpentine the same and equal facility to absorb oxygen. The comparatively slow rate at which the atmospheric oxidation of fresh turpentine proceeds, and the greater rate attained after the molecules have undergone that change which induces a rapid oxidation, is seen by the following figures, which relate to an experiment conducted some years ago upon about thirty gallons of turpentine in the presence of water:—

After 37 hours' exposure to a current of air 100 cc. of the aqueous solution contained					0·0651 grms.	H_2O_2.
,,	41	,,	,,	,,	0·2000	,,
,,	54	,,	,,	,,	0·3000	,,
,,	58	,,	,,	,,	0·4500	,,

As the oxidation of the oil goes on, its density gradually increases by the absorption of oxygen. This fact is illustrated by the following figures:—

In one experiment the original density of the oil of turpentine used, was 0·864.

After 24 hours' oxidation it was . . .	0·880
„ 28 „ „ „ . . .	0·881
„ 32 „ „ „ . . .	0·888
„ 44 „ „ „ . . .	0·949

In another experiment—

After 16 hours' oxidation it was . . .	0·8886
„ 20 „ „ „ . . .	0·8996
„ 26 „ „ „ . . .	0·9060
„ 39 „ „ „ . . .	0·9136
„ 46 „ „ „ . . .	0·9366
„ 48 „ „ „ . . .	0·9476
„ 300 „ „ „ . . .	1·2350

It thickens as it increases in density, and acquires a powerful odour resembling camphor and peppermint at once.

With the increase in the density of the oxidised oil, its boiling point also rises, as was shown by the experiment now to be described. The turpentine used in the experiment boiled as in column (1) :—

(1) Original oil.	(2) After 24 hours' oxidation.	(3) After 27 hours' oxidation.
10 per cent. distilled over at 157°C.	162°C.	165°C.
20 „ „ „ 159	165·5	166
30 „ „ „ 160	168	170
40 „ „ „ 160	171	171
50 „ „ „ 160·5	174	174
60 „ „ „ 161	181	185
70 „ „ „ 162	193	206
80 „ „ „ 164	210	—
90 „ „ „ 166	—	—

The results here tabulated, were arrived at by

taking 100cc. of each product, and subjecting to careful distillation, care being taken to record the temperature after the collection of every 10cc. distillate.

It has been stated above that, accompanying the peroxide of hydrogen in the aqueous solution which is obtained by atmospherically oxidising turpentine in presence of water, there is a small quantity of acetic, formic, and camphoric acids. There is also another substance present as a main constituent. When such a solution is evaporated to dryness on the water bath, all the acetic acid is dissipated in the vapour, and the peroxide of hydrogen is entirely decomposed, and there remains in the dish a dark-coloured matter which, when hot, is soft and viscid, and smells like melted sugar. On cooling, it sets into a hard, adhesive mass, about 95 per cent. of which is soluble in cold water. This soluble part, when analysed, was found to contain 63·245 per cent. carbon, 10·132 per cent. hydrogen, and 26·623 per cent. oxygen, from which percentage the empirical formula $C_{10}H_{18}O_3$ may be constructed. The aqueous solution of this new substance is very bitter, and possesses most remarkable antiseptic properties, of which more anon.

There is yet one other product which may be obtained from the aqueous solution resulting from the oxidation of turpentine over water. It is obtained in the free state, by merely subjecting the solution to distillation, when it passes over with the steam, and condenses into a light-coloured oil of a peculiar camphoraceous odour.

In recapitulation of the foregoing details, it may be stated that, when turpentine is exposed to the action of the atmosphere it absorbs oxygen, and gives rise to the production of a peculiar organic peroxide which remains dissolved in the body of the oil, and communicates thereto properties resembling those of ozone and peroxide of hydrogen. Inasmuch as the oil is volatile, these properties are communicated also to the surrounding atmosphere. If the oxidised oil be treated with water, or what amounts to the same thing, if the oxidation of the oil be conducted in the presence of water, then, on examination, the aqueous solution is found to contain peroxide of hydrogen, accompanied by a peculiar camphoraceous compound of the formula $C_{10}H_{18}O_3$. Along with these main products, are also found small quantities of acetic, formic, and camphoric acids, and a third body, which, when isolated, is of a camphoraceous and oily nature, etc.

The same products are obtained by the atmospheric oxidation of oil of eucalyptus, and every other essential oil which contains either cymene ($C_{10}H_{14}$), or a terpene (that is, a hydrocarbon of the formula $C_{10}H_{16}$).

This chapter may be fitly concluded by observing that the process of atmospheric oxidation of essential oils is an exact imitation of the one which necessarily occurs in nature with every plant that secretes these so-called oils, and which is, of course, attended with the same results. So far, therefore, as any properties of pine and euca-

lyptus forests may be connected with the special presence of peroxide of hydrogen, these are at once explained. In the next chapter, experiments will be described to show that the different products are powerfully antiseptic in character, and thus we shall finally be enabled to apply the derived knowledge in explanation of the processes of Nature's Hygiene, described in an earlier place.

Before proceeding, however, to these fresh studies, it will be convenient to so far anticipate the contents of the next chapter, as to assume that the products of the atmospheric oxidation of turpentine possess sanitary properties valuable enough in themselves to make it desirable that a solution embodying them should be commercially available.

Since, in this manufacture, it is desired to obtain the products of the atmospheric oxidation of turpentine for the sake of their sanitary properties, it becomes at once evident that the best result will be obtained by bringing the greatest quantity of air into intimate contact with a given quantity of turpentine under stated conditions. In practice this is effected as follows. A number of specially made Doulton-ware receivers are charged with water and turpentine in the proportions found to be best by experience, and the contents are maintained at a temperature of about 140°F. by surrounding the receivers with vats of water heated by steam. Under these conditions a current of air, obtained by a rotating fan or other means, is forced through each receiver during a prolonged period varying in practice

from 150 to 300 hours, incessantly. Under these circumstances the air current carries with it, when leaving the receivers, a large quantity of turpentine (or whatever other essential oil may be in use), and this is condensed by passing it into and out of various compartments of cold water, and up and down coke-scrubbers. The turpentine collects on the various surfaces of the cold water, and in the cisterns at the bottom of the coke-scrubbers, and from time to time it is drawn off and restored to the oxidisers. The chemical reactions which occur in these vessels have been already described in the preceding pages, so that here it is only necessary to recapitulate the main particulars. The turpentine absorbs the oxygen from the air, which is forced through it, and is thereby oxidised, giving rise to the production of camphoric peroxide, camphor, and various other substances of an oxidised nature. Some part of these at once dissolve in the water, which is below the turpentine in the receivers, and the camphoric peroxide is gradually resolved, also, by the water into peroxide of hydrogen and camphoric acid, which substances then dissolve in the water. At first, these changes proceed slowly, but they proceed with increasing rapidity from the first moment, the oil of turpentine growing yellowish red and thick as the operation goes on. It will be seen from this statement that the strength of the aqueous solution which forms underneath the turpentine must merely depend upon the time during which the process of air-oxidation is carried on. At the start we have only

water and turpentine in contact; but as the turpentine becomes oxidised, it yields to the water a large part of the substances formed by its atmospheric oxidation, together with those other substances which are produced by the secondary action of the water upon the oxidised oil.

The successful conduct of this process is not without considerable difficulty. It must be remembered that one of the ultimate products of the process is peroxide of hydrogen. This begins to form from the first moment, and continues to be produced during the whole time; but it is so readily decomposed again that, unless a number of precautions and conditions are carefully observed and maintained, there is a liability of obtaining a product containing no peroxide of hydrogen. Thus, if the temperature in the vats be allowed to rise too high, or if an insufficient depth of turpentine be kept in the oxidisers, there is a danger of decomposing the whole of the peroxide of hydrogen existing at the time of the neglect. On the other hand, if the temperature be too low, it forms very slowly.

In fact, the producer seeks to effect the greatest possible atmospheric oxidation of turpentine in the least given time, obtaining thereby a solution containing as much dissolved camphoraceous principles as possible, together with the maximum quantity of peroxide of hydrogen. This is done because, as will be explained hereafter, the oxidising powers of the aqueous solution are largely due to the presence of the peroxide of hydrogen, while the strictly antiseptic

characters are mainly traceable to the camphoraceous ingredients, notable amongst these being the substance with the empirical formula $C_{10}H_{18}O_3$.

At the termination of the manufacturing operation here so briefly traced, there remains in the receivers, floating upon the surface of the solution, a quantity of oxidised oil of turpentine containing some amount of the camphoric peroxide (resembling in all its properties peroxide of hydrogen), and a large amount of different oxidised substances at least identical in part with those existing in a dissolved state in the aqueous fluid. Being even more powerful as an antiseptic and disinfectant than the aqueous solution, although not so available in the liquid state on account of its oily and inflammable nature, it is utilised for making disinfecting powder and soaps. To make the powder it is incorporated with a suitable earthy basis, largely consisting of lime, and to make the soaps it is saponified with soda, and the product worked up with further quantities of soaps made from the normal sources.

CHAPTER VIII.

ANTISEPTIC AND DISINFECTING PROPERTIES OF THE OXIDATION-PRODUCTS OF THE ESSENTIAL OILS, WITH NOTES ON PRACTICAL DISINFECTION.*

THE present state of specific knowledge relating to the causes of infectious and contagious diseases being of such a very unsatisfactory nature that it cannot serve as a guide to practical disinfection, if considered apart from the much more extensive and general knowledge which forms the sum of human experience, it is best to disregard in this place, the various hypotheses of the causes of disease which so much occupy and distract the thoughts of all who take an interest in this important subject, and to confine ourselves to certain general propositions which may be safely used for the regulation of measures intended to prevent and arrest the spread of infectious and contagious diseases. This done, we can proceed to describe some simple experiments which have been made with the view of estimating the extent to which the sanitary reagent (Sanitas) originated by the author

* A great part of the substance of this chapter appeared as an article in the *Sanitary Record* of January 15th, 1880.

possesses those properties which qualify a disinfectant for universal use.

In the first place, it is matter of certain knowledge that the process of putrefaction is an insanitary one, and often originates disease. Innumerable outbreaks of disease have been traced to the putrefaction of animal and vegetable matters proceeding in or near human habitations. Now we have seen that putrefaction, beyond doubt, is initiated by certain low forms of animal life styled vibriones. These vibriones or their germs are practically ubiquitous, and in themselves are harmless, so far as we know, since most of the air we breathe and the water we drink, abound with them. It is only when they introduce themselves into dead organic media that they develope and produce those poisons which are dreaded by sanitarians. Septicæmia, and a number of foul diseases, well known in the hospitals, are undoubtedly due to the action of these same poisons, and it may well be that certain other even more dangerous diseases have the same or a similar origin.* However that may be, almost the only means, at present available, for determining the practical value of a disinfecting material, consists in ascertaining its power to prevent putrefaction. It must be clearly

* Since sanitas exerts an influence over those living agents which cause putrefaction (be it of a destructive nature to, or one of interference with, the normal function of vibriones), it is perfectly reasonable to infer that it exercises a corresponding influence upon other mycrophytes, and that this is so, experiments with various so-called ferments bear out.—Author.

understood that, whereas putrefaction is initiated by animal vibriones, many kinds of fermentation are caused by low vegetable forms of life, and there is no kind of evidence that either such forms of life or even the products to which they give rise, are harmful to man. The mould which grows in all damp, airy places, and the fungic growths which always attend upon slow decay, are examples of the forms of vegetable life now under consideration. So far, indeed, are such matters from being of a noxious character, that, beyond doubt, they serve a most sanitary purpose. By their agency the whole grand process of eremacausis (slow decay or slow combustion) is carried out. It is this process which ultimately burns all animal and vegetable compounds into carbonic acid, water, etc., which purely chemical substances are then available by plant life which requires them for sustenance. We do not want, therefore, to prevent slow decay or to render inactive those vegetable organisms which carry it out, but we only seek to prevent putrefaction and to arrest the activity of those animal germs which cause it.*

Our first proposition, then, is as follows:—"In addition to certain other properties, a disinfecting material must be competent to prevent and arrest putrefaction, considered apart from innocuous processes of fermentation."

Next, it is patent to all, that a chemical reagent

* Fungi have the property of absorbing oxygen by respiration, whereas putrefactive vibriones are killed by contact with oxygen. (*Pasteur.*)

intended for use as a disinfectant, need not be of the same strength or activity for all purposes. In other words, in certain cases a stronger form is required than in others. For instance, a reagent intended to preserve solid meat from decomposition, must be of a greater antiseptic strength than one intended only to preserve a dilute extract which might be made from a part of the same meat. Similarly, sewer-mud and the excreta call for the use of a stronger disinfecting material than, say, contaminated water or sweat. For whereas sewer-mud and excreta consist mainly of organic matters and these largely solid, impure water and sweat contain but a relatively small proportion of organic solids liable to putrefactive change. Thus, sweat contains water as its chief ingredient, and only about 0·5 to 1·25 per cent. of solid constituents, and these consist to a considerable extent of inorganic salts. It is, therefore, evident that the various matters which require antisepting and disinfecting, present every degree of potency presented between solid or exclusively organic matters, and dilute solutions or films containing scarcely any solid organic substances.

Our second proposition, then, is that, "A disinfecting material for public use is not required of the same strength for all purposes; indeed, two or more forms differing in strength are desirable."

Now, as matters of animal and vegetable origin are universally distributed, and find their way not merely into dust heaps and the sewers, but float about in the air, abound in waters, and even attach

themselves to articles of wear and furniture, it is quite impracticable to universally prevent the process of putrefaction. The process cannot be initiated or perpetuated if the matters (otherwise of a nature to undergo this process) are in intimate contact with oxygen, for Pasteur, who is the greatest authority upon this subject, has established the fact that putrefaction cannot set up, say, for instance, in an extract of beef, until all oxygen which may be present in the fluid has been first removed and consumed by certain other ferments of a vegetable nature. But, it is easy to understand that a variety of circumstances continually exist under which oxygen is shut out from direct contact with putrefactive vibriones, and immediately this happens, putrefaction sets in. Thus, although by proper methods of cleanliness and ventilation, a house may be set in order, especially if measures of disinfection are also resorted to, yet, as it is not possible to be always using disinfectants or ventilating or cleansing; or rather, since generally speaking, these sanitary proceedings are not sufficiently borne in mind and practised, we meet from time to time with the process of putrefaction going on in our midst, and until very recent years this was specially the case in our hospitals. It is, therefore, necessary, not only that a disinfecting material should be able to prevent and arrest putrefaction, but it must also have the property of oxidising or otherwise destroying the poisons to which that process gives rise. Hence, the third proposition is: "A disinfecting material should possess oxidising powers, so that

it can destroy the products of putrefaction as well as prevent and arrest the process which creates them."

Lastly, it is evident that to admit of universal application, a disinfectant must not merely possess those qualities which we have already studied, but it must also have such other qualities as fit it for universal use. In destroying septic poisons, care must be taken that the remedy shall not of itself kill the people, and so also in disinfecting inhabited apartments, the disinfecting material must not be inflammable or corrosive, neither must it stain the linen, the carpets, and the furniture. All this is imperative; for if reliance be placed upon disinfectants which either poison or stain, that reliance will be misplaced, since such reagents cannot be used as they should be used without destruction to life and property. Our last proposition, therefore, is, "A disinfectant qualified for universal use must not be poisonous in itself, and must give no stain. In other words, it must be fit for universal application, and hence must not be destructive to life or property."

As is well known, most of the essential oils, and certainly those of turpentine and eucalyptus, exercise very decided antiseptic characters. But, since in nature, these oils, when generated into the atmosphere, undergo oxidation in the presence of moisture, we must test the properties of the products of oxidation if we would obtain a proper understanding of the sanitary influences of the pine and the eucalyptus.

It was from the well-known oxidising effects of

peroxide of hydrogen, and its consequent use as a disinfectant, that the author was first led to the investigation of this branch of his subject; and during the earlier experiments, it was ascertained that beyond its well-known and valuable powers of oxidation it also exhibits very peculiar antiseptic influences. This was new to science.

Having thus been led to the subject, the investigation was continued with the view of ascertaining and explaining the antiseptic and disinfecting properties of the mixed aqueous solution which is obtained by oxidising oil of turpentine, or oil of eucalyptus, by air in the presence of water.

Towards the explanation of some of its properties the following experiments were communicated to the British Association Meeting of 1876 :—

Experiments with Peroxide of Hydrogen.

The solution which was employed was one of what is called "10-volumes strength," that is to say, it was capable of evolving ten times its own volume of oxygen gas when decomposed in accordance with the following equation :—

$$H_2O_2 + H_2O = O.$$

One hundred cubic centimetres of the solution would thus furnish 1000cc., or a litre of oxygen gas.

The experiments were conducted during hot summer weather.

Experiment 1.—10cc. of the peroxide of hydrogen added to 400cc. of fresh milk, preserved it from sour-

ing for six days. Oxygen gas was gradually evolved in the meantime. By the eleventh day only, the mixture became thick and sour.

Experiment 2.—5cc. preserved 47cc. grape-must from fermentation for some twenty-four hours, after which bubbles of oxygen gas escaped; finally, the mixture had an apple-like odour.

Experiment 3.—5cc. preserved 15cc. of white of egg, mixed with 10cc. water, perfectly fresh for many days.

Experiment 4.—5cc. preserved 400cc. "bitter beer," unaltered for twenty-six days; it then soured; fungus did not appear.

Experiment 5.—5cc. preserved 30cc. flour paste for six days free from sourness and mould.

Now the real quantities of peroxide of hydrogen and decomposable substances employed in the above experiments stand about as follows :—

					Per cent. of H_2O_2 =
1.	0·304 grm. H_2O_2	and over	400 grms.	milk .	0·076 per cent.
2.	0·152 „ H_2O_2	„	47 „	must .	0·3 „
3.	0·152 „ H_2O_2	„	15 „	white of egg solution	1·0 „
4.	0·152 „ H_2O_2	„	400 „	beer .	0·04 „
5.	0·152 „ H_2O_2	„	30 „	paste .	0·5 „

These experiments being only intended to show that peroxide of hydrogen possesses antiseptic and preserving powers, and not meant to determine the extent of such influences, at least demonstrated that its prophylactic energies are very great indeed.

Messrs. Guttmann and Frænkel, apparently unaware of this prior publication, gave confirmation to the

author's results by some experiments which were published in Virchow's *Archiv*, and to which the *Lancet* (June 22nd, 1878) subsequently directed further attention. These experiments confirmed the fact that peroxide of hydrogen preserves urine and meat infusions from putrefaction, while it also prevents the fermentation of grape-sugar.

The oxidising effects of peroxide of hydrogen upon animal and vegetable matters in a state of incipient change, or even of advanced decomposition, have been already considered in an earlier chapter. Nevertheless, its disinfecting properties are so important that it may be well to quote the following passage from Dr. Fox's work on Ozone (p. 228):—

"Peroxide of hydrogen is one of those powerful chemical agents which are concerned, like ozone, in the maintenance of the purity of the air. No known substance surpasses hydroxyl, as Dr. Frankland calls it, as an oxidising agent. Professor Taylor says:—'The oxygen contained in it amounts to 94 per cent. by weight; and according to Pelouze, in its maximum of concentration it will give off 475 times its volume of this gas. It has been employed as a disinfectant in sick rooms in the form of spray, with the greatest advantage; but is somewhat expensive for this purpose. It rapidly destroys all noxious gases, and is persistent in its action. The bodies of patients affected by the eruptive fevers are, by some physicians, bathed with it; whilst the clothes and letters of the sick are cleansed by sprinkling over them this oxygenated water.'"

Dr. Day, of Geelong, believes that it possesses the power of oxidising and annihilating the poisons of small-pox, scarlet fever, and typhoid fever, and has himself furnished some of the data* upon which he has arrived at this conclusion, which is evidently not without foundation. Between April 1873, and the same month of 1875, he treated fifty-one cases of scarlet fever, by anointing the bodies of his patients with lard containing peroxide of hydrogen; and in some cases he caused his patients to gargle a very dilute solution of the same reagent. Under this judicious treatment, there was extension of the disease to other persons only in four houses, and there were no deaths. Subsequently, Dr. Day treated other sixty-four cases, and of these only six proved fatal, whilst there was spreading of the disease only in three cases. These facts go far to teach the disinfecting value of peroxide of hydrogen; for while theorists continue to talk wildly about the germs of scarlet fever, there actually exists a substance which seems at once to cure the disease, and prevent the extension of the infection.

Although we cannot accurately define the precise manner in which the peroxide of hydrogen acts on the contagious matter thrown off from the skin, we can at least comprehend a possible mode of action. Just as the decomposition of chlorate of potassium takes place on heating, the heat set free in the breaking-up of one molecule into chloride of potassium and free oxygen, being sufficient to cause

* *British Medical Journal*, March 10th, 1877.

the decomposition of other molecules, so we can also imagine organic matter to exist in such a state of change as to exert a corresponding influence upon previously wholesome matter. If, however, the first molecule, whilst in the act of changing, could be so influenced by extraneous agency (for instance, artificial cooling) as to reduce the temperature, then the residual molecules of potassic chlorate would be left intact. Similarly, diseased matter may be rendered powerless to infect; and among agents capable of exerting this kind of influence, peroxide of hydrogen must be placed in a high position—one most probably due to its powerful oxidising effects.

In another chapter, reference has been made to the further fact that septic vibriones are killed by peroxide of hydrogen even when that solution is extremely dilute.

So much for peroxide of hydrogen.

Experiments with Camphoric Acid ($C_{10}H_{16}O_4$).

Camphoric acid being also a product of the atmospheric oxidation of turpentine conducted in the presence of moisture, some experiments were made with it, and it was found weight for weight to exhibit even more powerful antiseptic characters than salicylic acid, to which, as also to carbolic acid, it is chemically allied in certain respects.

0·3 grm. camphoric acid was sufficient to preserve 400cc. milk perfectly good for seven days in hot summer weather. After that time a scum formed, and by the eleventh day it was curdled and sour.

0·1 grm. of camphoric acid kept 50cc. of flour

paste good for eleven days. It went sour on the twelfth day.

0·1 grm. of camphoric acid preserved 50cc. grape juice permanently free from fermentation even when kept in a warm oven.

0·1 grm. kept 15cc. white of egg mixed with 10cc. water fresh for twenty-one days. The mixture became mouldy afterwards.

0·1 grm. kept 200cc. "bitter beer" unaltered for eleven days in an open vessel. It subsequently became covered with mildew.

Experiments with the Camphoraceous Substance of the Empirical Composition ($C_{10}H_{18}O_3$).

Equally striking are the antiseptic effects of the main product of the oxidation of turpentine which has been described in the last chapter. The experiments now to be described will sufficiently illustrate this fact.

A solution of white of egg* was made by beating up the whites of four eggs with a quantity of water and filtering from membranous parts. On examination the solution was found to contain 3·97 per cent. albumin dry at 100°C. Next, a solution of the camphoraceous substance containing 1·664 per cent. was prepared.

One stoppered bottle was charged with 20cc. of the albumin and 30cc. water; the mixture grew turbid, and began to stink on the sixth day. The

* Experience has shown me that it is much better to employ a dilute extract of meat for experiments of this kind, the indications being much sharper.—Author.

other bottle was charged with 20cc. of the albumin, 25cc. water, and 5cc. of the antiseptic fluid. This mixture kept perfectly sweet for at least thirteen days. That is to say, 0·0832 grm. ($C_{10}H_{18}O_3$) deferred the putrefaction of the albuminous solution at least eight days.

This experiment was repeated with stronger antiseptic and albuminous solutions with confirmative results.

In another experiment 0·75 grm. of the camphoraceous substance was dissolved in 110cc. of albumin solution (containing 0·8 grm. solid substance, dry at 100°c). The mixture kept clear and good from February 10th, 1879, till April 21st, after which it was no longer observed. At that time the solution contained its albumin in a perfectly unchanged state.

The Volatile Portions.

Antiseptic properties are also possessed by the more volatile portions of the solution (those to which the odour is chiefly due, and such as are obtained on distillation of the solution). This feature makes the reagent more valuable, since it is thus competent to act as an air purifier apart from a similar action presented by the peroxide of hydrogen. It is therefore seen that every constituent of the solution in question, contributes towards its total effect as an antiseptic and disinfectant. Of course it will be understood that acquaintance had been made with the characters of the solution as a whole, so far as this was possible, long before the experiments on its individual constituents were conducted, and also long

before the solution ever became known to the public in a commercial form, as "Sanitas."

First series of experiments with "Sanitas" solution.

The following were the experiments which were first put upon record in regard to this fluid.

Substance experimented with.	Amount of Sanitas used.	The Result.	Result in cases where the same amount of water, but no Sanitas, was employed.
40cc. water mixed with 10cc. white of egg.	5cc. after neutralisation with soda.	As fresh after 24 days as at first.	Began to stink on 2nd day.
50cc. Muscatel grape juice.	10cc. neutralised sanitas.	No observable fermentation.	Speedy fermentation of a normal character.
200cc. milk.	10cc. do.	Faintly acid 5th day; curdled on 7th.	Solid and sour on 3rd day.
60cc. urine.	10cc. do.	Unchanged so long as observed, viz., 7 days.	Bad 2nd day, and stank 3rd day.
10 grm. brain matter.	10cc. sanitas.	Sweet so long as noticed, viz., 15 days.	Bad on 3rd day.
100cc. milk.	10cc. do.	Sweet for 9 days.	Bad 2nd day.
100cc. flour paste.	10cc. do.	Good more than 19 days.	Stank 3rd day.
160cc. milk.	10cc. do.	Kept for 7 days.	Bad 2nd day.
160cc. beer.	10cc. do.	Good for more than 7 days.	Film on 2nd and bad on 3rd day.

The following experiments were made with a weaker antiseptic solution than that employed in the foregoing experiments.

A bottle was taken and charged with beer in apparently good condition, and containing 0·222 per cent. total acid, calculated as acetic. To this was added 0·14 per cent. of the sanitas. The bottle was then closed with a cork, through which passed a bent tube sealed with water, and kept in a room subject to considerable fluctuations in temperature. Gas was slowly evolved, but it appeared on examination to be mainly oxygen evolved from peroxide of hydrogen present in the sanitas, and not carbonic anhydride to any considerable extent. On examination after seven days it was found that the total acidity of the beer had not increased, thus showing that, as demonstrated by previous experiments, sanitas prevents the formation of acidity in beer by the action of secondary ferments.

Before describing any further experiments made with this solution, it must be explained that its antiseptic strength is almost in direct proportion to the amount of its soluble constituents, and these latter are strictly proportionate in quantity to the number of hours during which the turpentine is atmospherically oxidised. In other words, its antiseptic intensity depends upon its strength, and its strength is subject, within limits, to the will of the producer.

We can now proceed to study, by a description of more recently-conducted experiments (specially made for the purpose), how far sanitas, in the forms of

fluid and powder, is qualified for universal use as a disinfectant.

To be clear about this, let us here reproduce in a succinct form, the essential properties of such an agent: 1. In one form or another it must be competent to prevent and arrest all degrees of putrefaction. 2. It must oxidise or destroy the products of putrefactive change. 3. It must not be poisonous, must not stain, and must not be corrosive or inflammable, etc. (See Chapter V.)

Experiment 1.—A piece of lean beefsteak, about three inches square, was lightly rubbed over with two grammes of sanitas powder. It was kept exposed to the air for thirteen days, and up to the end there was no putrefaction or other apparent change. It dried up sweet and good.

Experiment 2.—The first experiment was repeated with the same quantity of powder, only in this case it was first mixed with five cubic centimetres of water, and applied to the meat as a wash. Consequently, not nearly the whole of the two grammes were finally placed upon the meat. It was kept for twenty days without any kind of change, except that it dried up entirely.

Experiment 3.—The first experiment was made also with the same quantity of 15 per cent. carbolic acid powder. The meat had a sour smell on the ninth day, and this odour persisted whilst the meat remained moist. Finally, it dried up.

Experiment 4.—Two ounces of flour were made into a paste, with two ounces of water. The paste

was divided into halves; one half was well mixed with 1·63 grammes sanitas powder, and the other with the same quantity of 15 per cent. carbolic acid powder. The mixtures were placed in test glasses, imperfectly covered with watch glasses. The sanitas paste kept absolutely unchanged for fifteen days; then small tufts of a fungic growth appeared on the sides of the glass where the liquor had been drawn up by capillary attraction out of contact with the sanitas powder. It did not otherwise alter during the subsequent twenty-three days, but the mixture remained as good as at first. From the carbolic paste a liquor separated, and this became gradually red. On the second day this was very distinct, and the colour gradually deepened to blood-red, a peculiar odour simultaneously developing, and the paste itself becoming discoloured to a considerable depth. These characters intensified during the thirty-eight days it was kept.

Experiment 5.—The whites of nineteen eggs were diluted with water until the whole measured 1,200 cubic centimetres. Quantities of eighty cubic centimetres each were now measured out into so many stoppered bottles, and to each bottle a quantity of sanitas or carbolic acid powder was now added, and the mixtures agitated from time to time. The quantities of powder used, ranged from 0·1 gramme upwards. The albuminous solution containing 0·1 gramme sanitas powder, kept quite unchanged for seven days, but became faint on the eighth day. All the other sanitas mixtures kept perfectly unchanged for the

whole period they were observed, namely, forty days. The mixture containing 0·1 gramme carbolic acid powder became faint on the second day, and decidedly stank on the third day. The mixture containing twice this quantity of powder became faint on the fifth day, and stank badly on the sixth day. The mixture with 0·5 gramme became doubtful on the twelfth day, but in this case the carbolic smell was too powerful* to be certain about the observation, although in the smaller amounts there was not the slightest doubt about the putrefactive odour and the presence of active vibriones. A special examination of the carbolic solutions was made in every case, and it was found that each one gave a precipitate on boiling, showing that in no case had all the albumin been coagulated by the carbolic acid.

Experiment 6.—A large piece of beef-steak, weighing more than one pound, was left in contact with about half-a-pint of fluid extract of beef until the whole was very putrescent. Ten grammes of sanitas powder were then added and the mixture agitated. In this way the putrescent odour was entirely destroyed, and only the smell of ammonia remained. The mixture was kept five days, and putrefaction

* The sense of smell serves but little purpose in experiments with carbolic acid, except in cases where that reagent is present only in very small amount. Its own odour is so intense that it suffices, even in small quantity, to cover or hide the putrescent odour entirely. It must be remembered that carbolic acid is not known to exercise any chemical effect which might render it valuable as a deodoriser. It does not destroy bad smells like oxidising agents; it only covers them by means of its own vapour, which in itself is dangerous and hurtful.

did not recommence. This experiment was also made with rotten mackerel, with a like result.

Experiment 7.—A quantity of freshly voided urine was well mixed with some fresh fæces, and the mixture placed in a stoppered bottle of considerable capacity, with a sprinkling of sanitas powder. The mixture was kept for more than 200 days, and was then free from putrescence and the life which causes it.

Before describing any further experiments, those already given, prove that sanitas powder is, weight for weight, more active in preventing putrefaction than fifteen per cent. carbolic acid powder, and that it will do what carbolic acid powder will not do, viz., destroy the poisonous products of putrefaction, when these have been allowed previously to form. It is also proved that sanitas powder is competent, when present in very small quantity, to entirely prevent and arrest the process of putrefaction, even when circumstances, otherwise, are most favourable to that process.

In illustration of the deodorising powers of sanitas powder one fact only needs mention. The recent Smithfield Club show (1879), where there were hundreds of animals, including more than fifty pigs (not to speak of the huge attendance of visitors), was deodorised by sanitas powder and fluid so effectually, that even the presence of the pigs could not be detected by their characteristic odour.

Sanitas powder not only prohibits and arrests the action of germ life, but it rapidly exerts an alterative effect on bioplastic substance generally, and

has the advantage of giving off antiseptic and oxidising vapours. It is, therefore, of service for disinfecting urinals, public markets, and other places, sewer-mud, cesspools, streets, etc. Moreover, it is cheap.

Experiment 8.—A large piece of fresh, lean beefsteak was cut up into pieces of more than one inch square; each piece was threaded with cotton, and then suspended in bottles containing ninety-six cubic centimetres of differently constituted solutions, composed of sanitas and water, in the proportions given below.

Solution used.		Remarks.
Pure Sanitas, No. 2.		The meat kept perfectly good as long as observed (in this case 50 days, but in other instances as long as 600 days).*
Sanitas.	Water.	
7 parts	1 . .	Kept absolutely unchanged so long as kept.
6 „	2 . .	The same.
5 „	3 . .	Kept quite free from putrescence for 40 days.
2 „	6 . .	„ „ „ 13 „
Pure water . . .		Began to stink on second day, and each day grew worse.

Even a ten per cent. solution of No. 2 Sanitas retards to a considerable extent the process of putrefaction, and if, then, the mixture be kept for many weeks,

* Animal matters may be thus preserved indefinitely, and hence the solution is very useful for preserving anatomical and other specimens.

although the solution will smell badly, the meat itself will be seen to have suffered little or no change, and, so far as observed in many experiments, will dry up on exposure to the air without further putrefaction. It seems that in the first stages of the immersion, the meat is so influenced by the sanitas that, while the extractive part which passes into solution may subsequently putrify, it (the meat) is protected against such change. It presents a par-boiled, healthy appearance, and is hard. In the stronger sanitas solutions the meat presents the same par-boiled look, and remains perfectly hard and sweet, while the solutions themselves also remain brilliant and good. This set of experiments just described was performed in vessels only loosely covered.

Experiment 9.—Two pounds of fresh beef-steak were minced and extracted at 60° centigrade, with 720 cubic centimetres water. The extract was cooled, filtered from fatty matter, and equal quantities placed in stoppered bottles with the quantities of sanitas, No. 2 fluid, shown below :—

Mixture.			When a putrid odour was observable.
Extract.	Water.	Sanitas.	
50 parts.	50	0 . .	Faint on the second day, very red and putrid on fourth day.
50 „	25	25 . .	Faint on thirtieth day; advanced very slowly.
50 „	12·5	37·5 .	Good so long as kept — viz., forty-two days.
50 „	0	50 . .	The same, of course.

Many other experiments of this kind have been made, all confirmative of the same general results. The beef extracts are considerably bleached by the peroxide of hydrogen in the sanitas, but generally speaking, the putridity, when it sets in, is coincident with more or less reappearance of the red colour, and the formation of a turbidity, which gradually grows into a deposit. Meat which has been preserved in sanitas solutions dries up unchanged on exposure to the air.

Experiment 10.—This experiment is given in illustration of the power which sanitas exerts in retarding fermentation, considered as a phenomenon apart from putrefaction.* A quarter of an ounce of flour made into paste with ten cubic centimetres water, began to ferment distinctly on the third day; mould was beginning to form, and the distinctive odour attending fermentation of this kind was plainly perceptible. On the eighth day, the mould appeared through the surface, and the fluid-layer at the top had become yellow, and of very bad odour. A similar paste made with ten cubic centimetres of Sanitas No. 2, instead of with water, remained absolutely unaltered for nine days. Then, a few white specks formed in the solution and grew slowly (not so rapidly as in the water paste). A paste made with twenty cubic cen-

* In the immediate vicinity of the room in which these experiments were conducted, hay and straw were being continually handled. This would, of course, favour the institution of fermentation in the pastes. It is interesting to bear in mind that so far as one constituent of sanitas is concerned, namely, peroxide of hydrogen, this might be considered to aid the development of fungi, seeing these respire, taking in oxygen and giving out carbonic anhydride.

timetres of the same sanitas remained quite intact for seventeen days, after which it was not observed. The vessels were only partially protected from the introduction of particles from without.

Experiment 11.—Pieces of fresh, lean beef, each two inches square, and half-inch thick, were immersed for two hours in the solutions given below, and then freely suspended in the air in a room kept at 60° Fahrenheit by day, but not heated by night (November).

Cubic cntmtrs.	Solution used.	Remarks.
100	Pure water . .	Solution became red and stank on third day, with turbidity.
100	10 % Sanitas, No. 2.	All these solutions remained free from red colour, turbidity, and smell so long as observed, viz., twelve days.
100	50 % „ .	
100	Pure Sanitas . .	
100	1 % Carbolic acid .	Became red; turbid on second day; turbidity increased each day.

All the pieces of meat dried up, free from any trace of putrefactive change, so that the object of the experiment was partially defeated. However, the history of the solutions affords some interesting information.

Experiment 12.—A large beaf-steak was cut up into a number of pieces of one inch square every way. These were threaded, kept moistened, and allowed to pass into advanced putrefaction. They were then suspended in solutions of 100 cubic centimetres capacity, and containing respectively, 12·5, 25, 37·5,

50, 62·5, 75, 87·5, and 100 per cent. Sanitas No. 2 fluid. To check the results one piece was suspended in water. This latter solution at once became red, and the putrefaction advanced daily; the meat gradually softening, becoming very red, and decreasing in volume and weight as it decomposed. The solution containing 12·5 per cent. sanitas blanched the meat, and removed the putrid odour. This, however, returned on the fifth day after, and the solution reddened again slowly. In all the other cases, the putrefaction was at once arrested and destroyed, and did not recommence during the twenty-seven days that the experiment was kept going. The pieces of meat presented at the end of this time, the blanched, par-boiled appearance previously referred to. They were all perfectly sweet, and on exposure to the air dried up entirely free from decomposition. A similar experiment was made with pieces of mackerel with the same general results, but the fishy smell prevented attainment of equally precise results.

Experiment 13.—A strong fluid extract of beef was kept during four weeks in a warm room, until, in fact, it had become terribly putrid. Quantities of this were placed in stoppered bottles, and then to these quantities, Sanitas No. 2 solution was added from a burette, until in each case the putrefactive odour could be no longer observed after shaking. In this way it was ascertained that 30 cubic centimetres of the sanitas fluid entirely deodorised 100 cubic centimetres of the putrid extract, thus confirming a property of sanitas referred to previously.

These latter experiments clearly establish the facts that Sanitas No. 2, even when diluted, say, with eight or ten times its bulk of water, is sufficiently powerful to prevent and arrest such putrefactive change as can ever be expected to occur upon the human body, or in inhabited apartments; and that when used in a less diluted or a pure state, its capacity for work increases accordingly. In common with numerous other experiments, which could be adduced if desirable, they confirm the general result which has been arrived at by many of the chief Boards of Health, Hospital Authorities, Medical Officers, and Surgeons, both in this country and abroad, which is, that sanitas, in the shape of powder and fluid, constitutes an economical and effective antiseptic, disinfectant, air purifier, and deodoriser. Finally, it alone, of all fluid disinfectants, is perfectly non-poisonous, stainless, and without corrosive properties. On the other hand, indeed, it is pleasantly aromatic in character, and is qualified for universal application. The use of sanitas for diffusing into the atmosphere of inhabited apartments and sick rooms, presents a really great advantage; it easily parts with oxygen, and it thus atones somewhat for that which is used up in insanitary processes. Then, as to cost, it must be remembered that poisonous disinfectants, and those which stain, become costly if the injury which is inflicted by using them in the only way that is effective, viz., abundantly, be also taken into account when determining their comparative values. Moreover, some real value must be

placed, apart from all other considerations, upon a reagent which suits the public taste and convenience.

Of course this chapter is not intended to pass the various disinfectants now before the public under any comparative review, but merely to explain the anti-malarial properties of the eucalyptus and the pine.

CHAPTER IX.

PINE AND EUCALYPTUS FORESTS.

IT was shown in Chapter VII. that for all practical purposes, most of the so-called essential oils, of which there are a great number, may be considered as identical in chemical composition. So that what was subsequently demonstrated to be true regarding the changes brought about by bringing air into contact with oil of turpentine and moisture, is also true of oil of eucalyptus.* This, however, is not merely a matter of inference, since the writer has examined the absorptive power of oil of eucalyptus for oxygen, and determined the fact that peroxide of hydrogen appears as an ultimate product of the reaction when conducted in the presence of moisture.

It has also been shown that the hygienic influence of pine and eucalyptus forests is undoubtedly due, chiefly at any rate, to the production in and around them of what may be called natural "sanitas," or in other words, the products of the atmospheric oxidation of their essential oils conducted in the pre-

* Messrs. Faust and Homeyer (*Deut. Chem. Ges. Ber.*, vii., pp. 63-66, and pp. 1429-1430) have shown oil of eucalyptus to consist mainly of terpene ($C_{10}H_{16}$) and cymene ($C_{10}H_{14}$). The oil of eucalyptus also contains an oxidised body, $C_{10}H_{14}O$, or $C_{10}H_{16}O$.

sence of moisture.* The intensity of the process is materially enhanced by the aid of direct sunlight.

Besides the affirmative facts already brought forward in support of this view, and of the further elucidation which follows hereafter, there is a fair amount of what may be called negative evidence. In the first place, other fast-growing trees do not possess, so far as is known, the power of freeing vast tracts of country from malarial fever; hence this power cannot be due to the mere drainage of the soil from its water. Then, again, both pine woods and eucalyptus groves are to be found in abundance upon hilly slopes and in mountainous districts, where, of course, there can be no waterlogging of the soil; and here the

* The value of essential oils as hygienic agents is well set forth by a recent report of Dr. Schomburgk (*Soc. of Arts Journal*, Aug. 22nd, 1879) on the progress and condition of the Botanic Garden and Government plantations at Adelaide, Australia. In this report it is stated that British India and Europe consume about 150,000 gallons of handkerchief perfume yearly, and the English revenue from eau-de-Cologne alone is about £8000 a year, while the total annual revenue from imported perfumes is estimated at £40,000. One perfume distillery at Cannes uses no less than 100,000 lbs. of acacia flowers, 140,000 lbs. of rose petals, 32,000 lbs. of jasmine blossoms, 20,000 lbs. of tube-rose, besides other fragrant flowers.

Dr. Schomburgk points out that in Australia, mignonette, sweet verbena, jasmine, rose, lavender, *Acacia famesiana*, heliotrope, rosemary, peppermint, violets, wallflower, laurel, orange, and the sweet scented geranium, all grow exceedingly well—indeed, with greater perfection than elsewhere. Australia, then, promises fair to produce commercially vast quantities of essential oils, which by their distribution and use produce hygienic results no less effectually than the eucalyptus trees, the chemical history of which is studied in this treatise.—Author.

influence of these trees is felt just as much as in other places. The affirmative evidence is no doubt, however, the most important; and as we have already made ourselves acquainted with its nature, we may now proceed to study its extent so far as is possible.

In a recent lecture* on the *Eucalyptus globulus*, Professor Bentley, who has made a special study of this tree, and the other members of the same genus, said: "In a lecture on the 'Eucalyptus,' which I delivered at the Royal Botanic Gardens, in Regent's Park, four years ago, I then stated my reasons for believing that the emanations from the leaves of groves of eucalyptus had some influence in destroying marshy miasms, and thus improving the healthiness of the district. Since then the very interesting researches of Kingzett have proved that under the influence of air and moisture, both peroxide of hydrogen and camphoric acid are formed from volatile oils—the former a powerful disinfectant, and the latter an antiseptic; and hence I think there can now be no doubt that the healthy influence of eucalyptus trees is, to some extent at least, and probably more than we imagine, due to the volatile emanations from the leaves under the influence of air and moisture, possessing direct disinfectant and antiseptic properties, and thus destroying the injurious effects of paludal miasms."

* *Pharm. Journ.*, May 4th, 1878. Prof. Bentley's former lecture was delivered on March 14th, 1874, and printed by order. Taylor & Francis, 1874.

In view of the facts which will be enumerated immediately, we may go even further than Prof. Bentley, and say that if not entirely, then at least mainly, the hygienic influence of the eucalyptus tree (and the pine tree) is due to the causes to which he alludes.

The *Eucalyptus globulus* belongs to the order *myrtaceæ*, which furnishes clove, oil of cajeput, and the pimento. The oil of eucalyptus, as obtained from the different species, of which there are more than 135, is practically of one and the same composition, although the odour, which is generally rich and camphoraceous, differs a little in the yields from the various kinds of tree.* The oil is chiefly stored in those pellucid glands which spread through-

* *Eucalyptus amygdalina.* The oil from this species is pale yellow, and has a camphoraceous lemon-like odour of a pungent nature. It boils at 165°C., and resinifies on exposure to the air. Sp. Gr. 0·881.

Eucalyptus oleosa. The oil has a camphoraceous odour, reminding at once of mint and turpentine. Boils at 161—177°C. Sp. Gr. = 0·911.

Eucalyptus sideroxylon. The oil boils at 161—177°C. Sp. Gr. 0·923.

Eucalyptus goniocalyx. Oil boils at 152—175°C. Very penetrating odour and pungent bitter taste.

Eucalyptus globulus. Oil smells like oil of cajeput, and has a mint-like taste. Boils at 144°—177°C. Sp. Gr. 0·917.

Eucalyptus obliqua. Boils at 171°—195°C. Sp. Gr. 0·899.

Eucalyptus odorata. Very aromatic odour. Boils at 157—199°C. Sp. Gr. 899—922.

Eucalyptus rostrata. Very much like *odorata* oil in odour and taste. Boils at 131°—181°C. Sp. Gr. ·918.

(See paper in *Zeitschr des œsterr. Apoth. Ver.*, 1878, 402; and *Pharm. Zeitung*, 1879, 220.)

out the leaves, and which may readily be seen by holding up the leaves to the light. The oil, however, seems to occur more or less throughout the tree.

M. Cloez found* that ten kilos of fresh leaves, taken from branches of an eucalyptus (species not named) killed by frost at the end of 1867, furnished by distillation with water 275 grms., or 2·5 per cent. by weight of oil. In another experiment (species again not named) eight kilos of dry leaves, gathered at Hyeres, gave, after keeping them one month, 489 grms., or 6 per cent.† From completely dry leaves, which had been kept five years, he obtained only 1·5 per cent. of oil.

The percentages given in the following table,‡ representing the amount of oil contained in the foliage of different species of the eucalyptus, were determined by Mr. Bosisto for the exhibition of 1862:—

Eucalyptus	amygdalina (or narrow-leaved peppermint tree)	3·313
„	oleosa	1·250
„	leucoxylon	1·060
„	goniocalyx	0·914
„	globulus (or blue gum-tree)	0·719
„	obliqua (or stringy bark-tree)	0·500

The next table is compiled from the paper of M. Raveret-Wattel,§ quoted in a previous chapter:—

* *Chem. News*, vol. xxvi., p. 63.

† Probably from *Eucalyptus amygdalina*, judging from the quantity.

‡ See *Chem. News*, vol. xxxix., p. 169.

§ *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

Eucalyptus amygdalina	5·75
„ oleosa	1·25
„ sideroxylon	1·00
„ goniocalyx	1·00
„ fabrorum	0·50
„ woolsii	0·18
„ rostrata (or red-gum tree) . . .	0·06

It is thus seen that, although the *Eucalyptus globulus* is the best known species, being a favourite on account of the rapidity of its growth and the luxuriance of its foliage, it is by no means one of the richest oil-yielding trees; and as Baron Ferdinand von Mueller (Director of the Victorian Botanical Department, Melbourne) therefore thinks, this species is not so important from a sanitary point of view as some of the others. Indeed, Mr. R. D. Adams, who obtained his information from Baron von Mueller, writes: "The respective hygienic value of various eucalypts may, to some extent, be judged from the percentage of oil in their foliage."*.

Even in the same species, the amount of oil varies somewhat according to the locality and season. *Eucalyptus rostrata*, one of the poorest in oils, grows well in periodically inundated places, and even in stagnant water which is not saline, and thus it is important for planting in malarious districts.

It is said that some species grow well in hot and others in cold climates, and thus there are eucalypts to suit the tropics of India and the more temperate regions in England. It must, however, be admitted that the English climate is, generally speaking, much

* *Chem. News*, vol. xxxix., p. 169.

too rigorous during the winter months for the young plants. Old trees would withstand these climatic influences, but they cannot grow old in England.

In his lecture on "Forest Culture,"* Baron von Mueller stated that Mr. Bosisto, a citizen of Melbourne, was then largely exporting the oil of eucalyptus, and was producing about 700lbs. a month. Since then, Mr. Bosisto, who has most industriously pursued this business, has given much attention to the hygienic value of the eucalypts. He became convinced that this virtue has some connection with the essential oil, and set himself to ascertain what he could about the quantity of oil and its probable sanitary effects, supposing it gets into the atmosphere through evaporation, aided by warm winds. He writes:† "The evidence of oil evaporation might thus be stated—that the desert scrub gums, after a winter of average rainfall, supplied the air with a continuous and even quantity of aromatic vapour, and kept up a rigorous vitality throughout the summer, and that a short season of rain and a long dry summer diminished the formation of oil, and so lessened the exhalation; but, on the other hand, the species tending seaward increased their quantity after a short winter."

It is said that sometimes the aroma of the volatile oil can be detected in the atmosphere even when travelling in the bush.

Now, in a previous chapter, attention has been

* *Pharm. Journ.*, New Series, vol. ii., p. 628.

† *Ibid.*, vol. v., p. 270.

called to the report of Mr. Skene, setting forth the distribution of eucalyptus forestry over Australia, and using these figures, Mr. Bosisto calculated that the mallee scrub in the colony of Victoria would retain in the leaves at one time no less than 4,843,872,000 gallons of oil, and the seaward species 280,891,000 gallons. In another calculation applying to the whole of New South Wales and South Australia, he showed that 96,877,440,000 gallons of oil may be held at one and the same moment in the leaves of trees massed together, and occupying a belt of country over which the hot winds blow. In the face of these figures, few could hesitate to come to the conclusion that forced itself upon Mr. Bosisto, viz., that the eucalyptus is a fever-destroying tree, and it owes this power to the oil which finds its way into the atmosphere.

As already stated, and as proved again and again, the oil has of itself certain antiseptic powers. These, however, are intensified, and become disinfectant also, so soon as the oil is oxidised by the atmospheric oxygen in contact with moisture. This has been explained in Chapter VII. From what is there described, it is probable that every molecule of oil of turpentine or oil of eucalyptus gives rise in this process of oxidation to a molecule of peroxide of hydrogen, and one of the camphoraceous body which has the approximate formula of $C_{10}H_{18}O_3$. Now if this be so (and any doubt there may be, can only apply to the quantity), then 96,897,440,000 gallons of eucalyptus oil can and must produce in

the atmosphere surrounding the forests no less than 92,785,023 tons of peroxide of hydrogen, and 507,587,945 tons of the camphoric substance $C_{10}H_{18}O_3$.

This quantity of peroxide of hydrogen could oxidise an enormously large amount of organic matter, rendering it harmless; for instance, say vegetable matter which may be undergoing decomposition, and thereby producing malarial fever until it becomes thoroughly antisepted, or oxidised, thereby removing the malarial poison. In this way the peroxide of hydrogen could part with nearly half its weight of nascent oxygen.

Then, again, the antiseptic powers of such an immense quantity of camphoraceous material can be conceived, if we reflect that a solution containing only a few grammes to the litre is sufficiently strong to preserve animal matter almost indefinitely, free from decomposition, as demonstrated by experiment.

The writer has not met with any figures showing the weight of foliage to the individual trees from which the sanitary value of a single tree could be estimated; but there can be no doubt that even this must be very considerable.

Now, what is true about the eucalyptus and its oil is true also of the pine-tree and its turpentine, and if anything, on even a more extensive scale. That this is so, is evident from the very great quantity of turpentine which finds its way into commerce; and even this amount, great as it is, represents but a mere fraction of that produced in nature.

Oil of turpentine is contained in the wood, bark,

leaves, and other parts of the members of the *coniferæ*, and the method by which it is distilled from the exudations of pines and firs will be referred to hereafter.

According to Planchon,* the French oil of turpentine is produced particularly by the *Pinus maritima* and *Pinus pinaster;* the German oil is yielded by *pinus sylvestris*, *L.*, *Abies pectinata*, and *A. excelsa*, *D.C;* the Venetian oil is extracted from *Larix Europæa;* and the English oil is a product yielded from the American turpentines produced by *Pinus tæda*, *L.*, and *P. Australis Mich.*

Dr. R. Godeffroy† has also recorded a similar statement, and furthermore adds that the German oil is also obtained from *Pinus vulgaris*, *P. picea*, and *P. rotunda.* He says that pine cone oil (*oleum abietis pini*) is obtained by distilling with water the cones of *abies pectinata;* dwarf-pine oil by similarly distilling the young tops and cones of *Pinus pumilio*, and pine-leaf oil from the leaves of *Pinus sylvestris* or *P. abies.*

The Swedish oil of turpentine (according to Morel) is obtained by distilling the wood itself; it is characterised by its odour, and by the presence of certain empyruematic substances.

All these different oils are classified as oil of turpentine; they differ, to some extent, in their boiling points (average 160°C), their specific gravity and

* See paper by Dr. Julius Morel, *Pharm. Journ.*, New Series, January 12th, 1878.

† *Pharm. Zeitung*, 1877, No. 81.

their action on polarised light, but in a more ultimate chemical sense they are identical, and merely represent so many different isomeric forms of terpene ($C_{10}H_{16}$). As produced in nature, they are accompanied with certain oxidised products, and doubtless the natural resins and gums are formed by the action of atmospheric oxygen upon the terpenes existing in the trees.

The process* by which the turpentine is gene-

* The following further particulars I have derived from the papers of Dr. Julius Morel, published in the *Pharmaceutical Journal*, Ser. 3, vol. viii.:—The tapping of turpentine may continue over 150 years, and more profitably if, while the tree is young, it is allowed an occasional period of rest. The process of "hacking" is carried on during the months from May to September. A vigorous pine standing alone will yield annually, twenty to forty kilogrammes (44 lbs. to 88 lbs.) of "crude turpentine;" but if the trees be massed together, the individual yield amounts only to about five or six kilogrammes. As already stated, the product thus obtained is called crude, or brute turpentine. A sample which had been obtained from the Silver and Spanish fir-trees (Strasburg turpentine) was analysed by Caillot in 1830, with the following results:—

Volatile oil	33·50 per cent.
Resin insoluble in alcohol	6·20 ,,
Abietine (kind of resin)	10·85 ,,
Abietic acid (resin acid)	46·39 ,,
Aqueous extract containing succinic acid	0·85 ,,
Loss	2·21 ,,
	100·00

During the flow of the crude turpentine there forms upon the bark a concrete mass, consisting of crude turpentine from which the volatile oil has been evaporated by atmospheric influences. This concreted substance is known as "gum thus," or "galipot." A yet cruder product of the same nature is known as "barras."

rally obtained from the trees, consists in tapping them at regular intervals, and collecting the crude or brute turpentine constituting a thick resinous mass which is afterwards subjected to distillation, either with water, or steam, or otherwise.

It is probable that the hygienic influence of the pine is much greater than that of the eucalyptus, since it has a much wider and more extensive distribution in nature. Thus, Russia alone has 500,000,000 acres of forestry largely consisting of pine trees; while, as is well known, a large industry is carried on in turpentine products yielded by the pines

The pure oil of turpentine is obtained from the crude turpentine containing it together with certain hydrated and oxidised substances (resins, etc.), by various processes of distillation. The distillation may be conducted in the presence of water, or in a current of steam, or by itself, etc. The yield of oil amounts to from 15 to 30 per cent. of the crude product, and averages about 25 per cent.

Strasburg turpentine is very siccative, and is furnished by the Pectinate fir-tree, Silver and Spanish fir-trees. This tree inhabits almost all the mountains of Central Europe, the Alps, Pyrenees, etc. It is common on the Vosges and in the Black Forest, where it constitutes high and dense forests.

Venice turpentine is not very siccative, and is yielded by *Larix Europæa*, or common larch. This tree will grow upon almost any soil, but prospers best in a clear, dry atmosphere, or a cold-bottomed soil. It thrives at 1800 feet above the sea level, and attains a higher level even than the Scotch pine. A tree of fifty or sixty years of age can yield from three to five kilos of crude turpentine annually, for five or six years. Canada balsam, or Canadian turpentine, is siccative, and is obtained from *Abies balsamea*. Burgundy pitch is obtained from *Abies Excelsa* DC., and contains a large quantity of resinous matter. Colophony is the name of the resinous matter which is left behind in the retorts used for the distillation of the pure oil.

and firs of not only Russia, but also Switzerland, Germany, Sweden, and Austria. The European trade, however, is not so large as the American one, which now furnishes most of the turpentine met with in commerce.

In illustration of the extent of pine forestry in America, it is interesting to notice a remarkable shower of pollen grains which fell in the north-eastern part of Pennsylvania on the morning of March 17th, 1879, and covered an area of more than 2,500 square miles. The pollen was that of *Pinus Australis* from the Southern States, and it was believed to have been carried a distance of over 500 miles.*

Curiously enough, a similar occurrence was recently recorded in the *Times*† as having been noticed at Windsor, Slough, and in that neighbourhood generally. The pollen, which was probably derived from *Pinus Sylvestris*, and blown from Windsor Forest, was at first thought by the people residing in the district to be sulphur.

Besides the vast pine forests of America, Russia, and Sweden, there are the pine woods of Arcachon, famous for their healthfulness, and particularly grateful to persons suffering from pulmonary affections.

Even in our own country pine woods abound, not merely in Scotland, but scattered over the entire area. They are to be found so near to London as Bournemouth, Upton, and Weybridge.

From this vast extent of pine forestry distributed

* *Hardwicke's Science Gossip*, June 2nd, 1879.

† See *Nature*, June 1878.

all over the world, an incalculable quantity of oil of turpentine finds its way into the atmosphere, just in the same manner as does the volatile oil of the eucalyptus. Of course this process of oil evaporation proceeds far more rapidly in warmer climates, and is much more noticeable in our own woods in summer than in winter. All who have visited St. George's Hills at Weybridge in the summer, must have remarked the delicious aromatic perfume that hangs about the atmosphere. On a warm day, the air is balmy with the odour of the oily bodies which are being incessantly poured into it, there to undergo those changes which are attended with such important hygienic results.

By the natural atmospheric oxidation of the oils of eucalyptus and turpentine there is produced an almost illimitable amount of peroxide of hydrogen and camphoraceous matters which must, perforce, act according to their chemical natures upon the pestilence that may be floating in the air, and upon the animal and vegetable matters that may be rotting in the soil.

What is done by pine and eucalyptus forests on this grand scale is carried out in miniature by every plant or flower which owes its perfume to the essential oil which it secretes.

The Governments of this and other countries ought, therefore, never to lose sight of the value of eucalyptus and pine plantations. Valleys and swamps may, by their agency, be freed from malarial fever; and in the place of a poisonous atmosphere,

they substitute a state of balminess and purity at once luxurious and healthful.

It is possible to dwell very largely on this theme, but it is hoped that enough has been said and sufficient evidence brought forward to prove conclusively that among the processes of Nature's Hygiene there are few more extensive, or more important, than that by the study of which the author was led to the discovery of the disinfectant named "Sanitas."

In the foregoing pages the author has, of necessity, been obliged to refer a great deal to his own work and writings; but if that call for excuse, he trusts his readers will justify him by reason of the great importance of the subject, and its universal interest.

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